AD-A051 128 MASSACHUSETTS INST OF TECH LEXINGTON LINCOLN LAB F/G 17/7
VERIFICATION OF DABS SENSOR SURVEILLANCE PERFORMANCE (ATCRBS MO--ETC(U)
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Project Report
Discrete Address Beacon System

ATC-79

W. I. Wells

Verification of DABS Sensor Surveillance Performance (ATCRBS Mode) at Typical ASR Sites Throughout CONUS

20 December 1977

AD NO.
DDC FILE COPY

Prepared for the Federal Aviation Administration by

Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LEXINGTON, MASSACHUSETTS

Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151.

(19) 77/113

Technical Report Documentation Page

1. Report No. (18) FAA-RD-77-113

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle (6)
Verification of DABS Sensor Surveillance Performance (ATCRBS Mode) at Typical ASR Sites Throughout CONUS

5. Report Date (11) 20 De[redacted]77

6. Performing Organization Code (12) 52p

7. Author(s) (10) W. I. Wells

8. Performing Organization Report No. (14) ATC-79

9. Performing Organization Name and Address
Massachusetts Institute of Technology
Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173

10. Work Unit No. (TRAIS)
Proj. No. 034-241-012

11. Contract or Grant No.
DOT-FA72-WAI-261

12. Sponsoring Agency Name and Address
Department of Transportation
Federal Aviation Administration
Systems Research and Development Service
Washington, DC 20591

13. Type of Report and Period Covered (9) Project Rep[redacted]t

14. Sponsoring Agency Code

15. Supplementary Notes
The work reported in this document was performed at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology under Air Force Contract F19628-78-C-0002.
(15) DOT-FA72WAI-261

16. Abstract

A Transportable Measurement Facility (TMF) incorporating antenna, r-f, and reply processing elements of a Discrete Address Beacon System (DABS) sensor has been sited at, and in the vicinity of, several FAA terminal ASR's throughout the United States. Data collected at these sites have been thoroughly analyzed to verify the design of the DABS sensor and to establish the need for design refinements. This report presents the results that pertain to DABS and ATCRBS Mode range and azimuth accuracy and to the total ATCRBS Mode reply processing performance. It is shown that both range and azimuth accuracies for the DABS sensor are a factor of four to five better than those provided by existing ARTS (BI-4) interrogators, and that the average blip/scan ratio is 98% or better, dropping only a few percentage points in crossing track situations.

17. Key Words
Air Traffic Control
Radar Beacon System
Field Performance Evaluation
Monopulse Azimuth Estimation

18. Distribution Statement
Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	52	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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I. INTRODUCTION

As a part of the DABS[1] Design Validation and Refinement task[2], measurements were made* of the performance of key DABS sensor elements under a wide variety of site and traffic situations. DABS had previously been tested extensively at the DABS Experimental Facility (DABSEF) located in Lexington, Massachusetts. The goal of these field performance measurements was increased assurance that the engineering developmental sensors being procured from industry would meet expectations when installed at typical FAA sites.

In order to perform these measurements a Transportable Measurements Facility (TMF)[2] was designed and built to implement the DABS sensor "front end" including DABS/ATCRBS transmitter, two antennas, monopulse receivers, and DABS/ATCRBS reply detectors. Digital data were recorded for computer processing at the Laboratory in Lexington. This computer processing implemented the remainder of the DABS sensor functions and also performed various recording and analysis functions.

Correct operation of the TMF was verified initially by comparison with DABSEF while co-located, and while located a half mile away at Hanscom Field, Bedford (Mass.). Following verification, the TMF was taken to eleven sites where a variety of tests were conducted. A brief survey of the tests is included in the next section. This report covers sensor range and monopulse azimuth accuracy performance on DABS and ATCRBS equipped aircraft, and the

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*During the last half of 1976 and early 1977.

total reply processing performance of the ATCRBS mode of DABS, including blip scan ratio, track continuity, code and altitude reliability, and performance in crossing track situations.

A. Survey of TMF Tests

1. Objectives

TMF tests were structured to support sensor design validation and refinement and included operation with DABS signals and with ATCRBS signals. A companion objective was the collection of data to 'characterize' different sites. Since the performance of a radar or beacon depends upon the propagation conditions at the local site, it was necessary to determine which factors could be attributed to the sensor design itself and which were site dependent. The site characterization experiments usually involved circular flight paths and employed dedicated aircraft.

The principal antenna used was the DABS modification of the ASR-7 antenna (radar feed modified to include a beacon monopulse feed.) A second antenna, a split 'hogtrough'* (with integral omni), so arranged as to give a suitable monopulse response, permitted some isolation of pattern dependent effects.

2. Site Selection

The TMF sites selected were Boston, Washington, D.C., Philadelphia, Los Angeles, Salt Lake City, Las Vegas, and Warwick, R.I. Boston was close to

---

*Designed and built by Cossor, Ltd, of the UK.

the Laboratory and hence a good first place to shake down operating procedures. In addition, Boston had been under surveillance by DABSEF for two years, and data taken simultaneous with DABSEF and the Boston ARTS showed ample evidence of false target reflection problems.

Washington, D.C. has reported false target problems, low round-reliability, etc., and has been the subject of several studies. Los Angeles has been used for years as the proverbial "worst case" against which system designs are compared. "LA 1995" was the goal for satisfactory DABS design with an interim "LA 1982" when the ATCRBS problem would peak there.

Philadelphia (Clementon, N.J.) is the planned site for the third Engineering Development Model DABS and the site of the tentatively planned DABS operational trials, so it was important that TMF data be taken there.

Since the FAA is considering a move from its present site at Salt Lake City, it was requested that the TMF take data at two prospective sites, one near the present site, and another several miles away.

At Las Vegas, the radar/beacon site is in a "bowl" surrounded by mountains. Placing the TMF at this site thus afforded an opportunity to test the operation of the sensor functions in a severe multipath environment.

The Warwick, R.I. site was selected for study of multi-sensor surveillance netting with the TMF "cooperating" (not in real time, but in subsequent simulation exercises) with the DABS experimental sensor at DABSEF.

3. Improved Siting

Advances in primary radar signal processing[3] promise to reduce ground clutter significantly so that improved siting of the radar/beacon sensors can

be considered. At three of the TMF sites -- Boston, Philadelphia, and Los Angeles -- a remote site was also selected (Deer Island, Clementon, and Brea, respectively) to determine if adequate or improved coverage of the airport could be achieved from a site offering promise of long range coverage.

4. Data Collection

Many experiments were conducted at each site with each experiment generally providing one or more magnetic tapes containing 20 minutes to an hour of data. Table I-1 shows the numbers of experiments conducted at each site.

In the first group are the system calibration runs done after each move of the equipment. The antenna pattern runs were made at least once for each antenna at each site to determine the influence of the terrain on the patterns. Then as part of preparation for each data run, or sequence of runs, a monopulse calibration was made to verify correct surveillance operation.

The second group listed in Table I-1 are the normal sensor operational modes for a DABS sensor. These include data from both antennas. The remainder of this report is concerned with the TMF Normal Mode ATCRBS experiments.

The third group used TMF in some of its special modes, for purposes such as recording fruit and other interference.

B. Comparison of TMF and ARTS (BI-4) Performance

Nearly all of the TMF sites were near ARTS (BI-4) installations whose coverage very closely approximated that of the TMF. Hence, by merely arranging ahead of time for the simultaneous recording of ARTS data, a unique

TABLE I-1

NUMBERS OF TESTS IN EACH TEST MODE PERFORMED AT EACH TEST SITE

	Site -	Boston	Deer Island	Washington, D.C.	Clementon, N.J.	Philadelphia	Los Angeles	Brea, CA.	Salt Lake City	Layton, Utah	Las Vegas	Warwick, R.I.
Calibration Set Up, etc.	Internal System Calibration	1	1	1	1	1	1	1	2	1	1	Ø
	ASR-7 Antenna Patterns	3	1	1	1	2	1	3	1	1	1	1
	Cossor Antenna Pattern	1	1	4	1	2	1	3	1	1	1	3
	ASR-7 Antenna Calibration	28	12	11	22	14	21	18	6	2	4	8
	Cossor Antenna Calibration	5	10	13	19	13	8	5	4	3	4	8
Normal Sensor Modes	DABS	Ø	8	18	23	35	12	29	Ø	Ø	2	Ø
	ATCRBS w/ASR-7 Ant.	33	16	15	31	13	29	22	7	8	7	8
	ATCRBS w/Cossor Ant.	5	4	3	5	3	5	6	4	3	4	6
Special Recording Modes	ATCRBS-ASR-7 Listen Only	Ø	3	Ø	1	1	3	Ø	2	Ø	1	Ø
	ATCRBS-Cossor Listen Only	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1	Ø
	DABS Listen Only	Ø	1	Ø	Ø	2	1	2	Ø	Ø	Ø	Ø
	ATCRBS Spotlight	Ø	Ø	3	3	2	3	Ø	Ø	Ø	Ø	Ø

opportunity was available for the detailed comparison, under nearly identical conditions, of DABS performance with that of today's ATC surveillance standard, ARTS. A number of such comparison experiments were run, and the resulting ARTS "extraction tape" obtained and forwarded to DABSEF for processing with the corresponding TMF data tape.

II. PERFORMANCE OF THE ATCRBS MODE OF DABS

A. ATCRBS Reply Processing

The flowchart shown in Fig. II-1 depicts quantitatively the way in which replies are sorted as 'reply processing' proceeds. This same format will be used in later sections to compare TMF performance and ARTS (BI-4) performance. Figure II-1 is a composite of TMF data made by combining the performance of 54 TMF tests taken at the eleven sites listed in Table I-1. Performance percentages were weighted according to the number of qualified (defined in Fig. II-1) reports occurring in each test.

The ATCRBS Mode reply processor assembles one or more replies into an initial report. If a single mainbeam reply occurs that is not geographically near another reply, it is assumed by the reply processor to be fruit and dropped. All sidelobe replies are also dropped by the RSLS. The only fruit to reach surveillance processing are one-hit reports that happen to be near another reply (but fail a code or altitude correlation test) and two hit reports with one Mode C and one Mode A reply. The first step in surveillance processing is to further edit the report stream to decide which reports should be carried forward. In Fig. II-1 the percent of reports edited out (10.54%) indicates that even with most fruit dropped in the reply processor, about 10% of the reports in addition can be edited out due to various causes such as code/altitude swap (see Ref. 4 for a complete description).

The format of Fig. II-1 always results in 100% being the number of reports that pass through the editing process. Note that with ARTS (BI-4)

```
COMBT
                         REPLY PROCESSOR
                               |
                               |
                            110.54 %
                               |
                               |
                         REPORT EDITING
                               |
                               __  10.54 %  EDITED OUT
                               |
                   (  65.9  % ALT.EQUIPPED)
                               |
                               |
               REAL            V              FALSE
             ----------------------------------------
             |                                       |
          99.30 %                                  0.70  %
             |                                       |
        TRACK INITIATION                    TRACK INITIATION
             |                                       |
             |__>  6.04 % _______   0.45 % <__|
             |                |                      |
             |             DID NOT                   |
             |             START A                   |
             |              TRACK                    |
             |                                       |
          93.26  %  (MADE REAL        0.25  % (MADE FALSE
             |     TRACKS)                     TRACKS)
             |
             |
             -----------------
                               |
                               |
                               V
PERFORMANCE SUMMARY FOR 'QUALIFIED' REPORTS(*):
```

	ALL	CROSSING
BLIP/SCAN	97.45 %	96.14 %
OLD ALTITUDE	1.19 %	2.59 %
OLD CODE	0.58 %	2.34 %
NO. OF QUAL. TRACKS	182.	
TRACK NO. ERROR FRACT.		
2 TRKS ON ONE A/C.	0.01	
2 A/C ON ONE TRK.	0.01	
RANGE ERROR STD. DEV.	22.69 FT.	
AZIMUTH ERROR STD.DEV.	0.04 DEG.	

(*)QUALIFIED REPORTS ARE FROM TRACKS THAT:
- ARE ASSOCIATED WITH 10 OR MORE REPORTS
- OCCUR AT AN ELEVATION ANGLE BETWEEN .5 AND 40 DEGREES
- ARE AT A RANGE BETWEEN 2 AND 45 N. MILES
- CORRESPOND TO AN AIRCRAFT WITH ENCODING ALTIMETER.

Fig. II-1. Reply processing flow diagram: average over all sites (54 tests).

data there is no editing step because defruiting, if any, precedes the recording and the remaining reports do not possess the necessary attributes to permit further editing.

Only a certain percentage of all the reports passing through the initial editing process are from aircraft equipped with encoding altimeters. This percentage is noted (65.9%).

The DABS software programs perform false target tests (based on geometry) to determine which reports and tracks are real and which are false. Though in the actual programs the tagging of real and false is accomplished during track initiation, the process is easier to follow as shown in Fig. II-1 where 99.30% of all reports are finally called real and 0.70% are called false.

The real reports were processed as follows: 93.26% became associated with real tracks and 6.04% were used to try to initiate tracks never started. Similarly, some of the false reports (0.45%) were used to try to initiate tracks that did not start, and some (0.25%) actually combined to form false tracks. Note that in the DABS sensor ATCRBS mode processing, these false reports and false tracks are flagged so they do not need to be processed further.

The ARTS (BI-4) data were processed through the same geometric false target tests. However in this case, ARTS does not flag the false reports and tracks, and they proceed through the system for display to the controllers.

B. Qualified Tracks

To confidently report system performance it is important to be as sure as possible where the aircraft were and what they were doing, and that the data were not being perturbed by some unknown anomalous propagation condition. Thus a subset of all tracks was selected and referred to as "qualified". Each of these tracks had to have 10 or more reports so as to sort out possible spurious or reflection tracks that might have passed the false track filter. It also had to have an altitude code to permit confirming an elevation between 0.5° and 40°. Below 0.5° the actual skyline came into play in a non-repeatable way from site-to-site. The range had to be between 2 nmi and 45 nmi. The 2 nmi and 40° limits simply recognize the expected performance degradation in the "cone of silence" above the radar. Most of the TMF recordings were made at maximum ranges of 60 nmi to 200 nmi, but to enable comparison with ARTS (BI-4), a standard cut-off of 45 nmi was chósen.

The percentages given in the upper portion of the flowchart shown in Fig. II-1 include all data taken even if the recording was made to 200 nmi. The statistics at the bottom of the figure pertain only to those tracks that are "qualified", i.e., fell within the 2 to 45 nmi range and 0.5 to 40° elevation limits.

C. Reply Process Performance Summary

At the bottom of Fig. II-1 performance is summarized for qualified reports in two columns. The "All" column refers to the reports from all the

qualified tracks. The "Crossing" column refers to the reports from qualified tracks when they were crossing other tracks (i.e., within 2 nmi range and 1 beamwidth in azimuth).

A DABS sensor interrogates each ATCRBS-equipped aircraft with Mode A and Mode C each scan) (approximately twice each scan). If the Mode C altitude is received with all bits 'high confidence', it is sent out that way. If one or more of the bits is "low confidence,' the altitude is flagged, which means that a new altitude update was not made this scan. Each time that occurs, it is denoted as an "old" altitude, (1.19%, 2.59%) since a track file would not be updated. There would be no error, however, unless the aircraft simultaneously changed altitude. Similarly, whenever the Mode A code is not all 'high confidence,' we say that the code update is old (0.58%, 2.34%). Both these quantities can be determined for the ARTS (BI-4) as well as for TMF.

In addition it is possible by post-test track filtering, etc., to determine how often an actual erronous track would have occurred. '2 TRKS ON ONE A/C' (.01) indicates the fraction of the total number of qualified tracks (182) which would have involved two tracks being established on one aircraft. Likewise, '2 A/C ON ONE TRK' (.01) the fraction which would have permitted two aircraft to have been erroneously labeled as on one track.

The last two statistics in Fig. II-1 are the range (22.69 ft.) and azimuth (0.04 deg.) error standard deviations (i.e., jitter exclusive of bias). These are derived by a process of fitting a 2nd order polynomial and editing out turns and outlier data for selected tracks[5].

III. TMF/ARTS COMPARISONS

Figures III-1 (a, b) through III-6 (a, b) show one test from each of the six sites where TMF and ARTS (BI-4) data were recorded simultaneously, and the TMF was located near the ASR. In each figure (Part(a)), the standard data from the ARTS (BI-4) is on the left, and for the TMF is on the right. Part (b) of each figure shows a plot of the reports as seen by ARTS (BI-4) and by the TMF.

With few exceptions, the TMF data show improved performance in every category. The blip/scan ratios both for normal and for crossing track situations are 5 to 15 percentage points higher. In both range and azimuth accuracy, the DABS improvement is a factor of 3 to 6.

Having viewed some data from each site, the reader will have perceived that the statistics do not vary substantially from site-to-site (except for the percentage of false reports -- as it should because false reports are caused by local reflections). In view of this, all the data from Figs. III-1 through III-6 have been combined and presented as an "average" ATCRBS Mode of DABS and ARTS (BI-4) comparison in Fig. III-7. In this figure the improved performance of the TMF can be seen in every category.

In addition note that generally the performance of both the TMF and ARTS (BI-4) degrades in crossing track situations. This is the expected result of synchronous garble. Though the effect is noticeable, the TMF rarely loses a track or drops its blip/scan ratio greatly. Altitude and the code updates (old altitude and old code) are also affected by synchronous garble, but this is not serious unless it actually creates an error.

ATC-79(III-1a)

```
2090C
                  REPLY PROCESSOR
                         |
                         |
                       100. %
                         |
                         |
                  REPORT EDITING
                         |
                         |__  0. %  EDITED OUT
                         |
         (  57.46   % ALT.EQUIPPED)
                         |
                         |
     REAL                V                 FALSE
      ______________________________________
      |                                    |
    99.82 %                              0.18 %
      |                                    |
  TRACK INITIATION                    TRACK INITIATION
      |                                    |
      |__>  3.73 % _______   0.13 % <__|
      |                |                   |
      |             DID NOT                |
      |             START A                |
      |              TRACK                 |
      |                                    |
    96.09  %  (MADE REAL      0.05  % (MADE FALSE
      |        TRACKS)                     TRACKS)
      |
      |
      __________________
                        |
                        |
                        V
PERFORMANCE SUMMARY FOR 'QUALIFIED' REPORTS(*):

                                  ALL          CROSSING

  BLIP/SCAN                      97.8  %      91.5  %
  OLD ALTITUDE                    0.6  %       4.1  %
  OLD CODE                        0.7  %       5.2  %
  NO. OF QUAL. TRACKS            49.
  TRACK NO. ERROR FRACT.
     2 TRKS ON ONE A/C.           0.0816
     2 A/C  ON ONE TRK.           0.
  RANGE ERROR STD. DEV.         134.82  FT.
  AZIMUTH ERROR STD.DEV.          0.196 DEG.

(*)QUALIFIED REPORTS ARE FROM TRACKS THAT:
     - ARE ASSOCIATED WITH 10 OR MORE REPORTS
     - OCCUR AT AN ELEVATION ANGLE BETWEEN .5 AND 40 DEGREES
     - ARE AT A RANGE BETWEEN 2 AND 45 N. MILES
     - CORRESPOND TO AN AIRCRAFT WITH ENCODING ALTIMETER.
```

ARTS (BI-4)

```
2090T
                  REPLY PROCESSOR
                         |
                         |
                      112.49 %
                         |
                         |
                  REPORT EDITING
                         |
                         |__  12.49 %  EDITED OUT
                         |
         (  58.55   % ALT.EQUIPPED)
                         |
                         |
     REAL                V                 FALSE
      ______________________________________
      |                                    |
    99.53 %                              0.48 %
      |                                    |
  TRACK INITIATION                    TRACK INITIATION
      |                                    |
      |__>  4. % _______      0.37 % <__|
      |                |                   |
      |             DID NOT                |
      |             START A                |
      |              TRACK                 |
      |                                    |
    95.53  %  (MADE REAL      0.11  % (MADE FALSE
      |        TRACKS)                     TRACKS)
      |
      |
      __________________
                        |
                        |
                        V
PERFORMANCE SUMMARY FOR 'QUALIFIED' REPORTS(*):

                                  ALL          CROSSING

  BLIP/SCAN                      98.6  %      100.  %
  OLD ALTITUDE                    0.4  %       0.0 %
  OLD CODE                        0.1  %       0.0 %
  NO. OF QUAL. TRACKS            56.
  TRACK NO. ERROR FRACT.
     2 TRKS ON ONE A/C.           0.0178
     2 A/C  ON ONE TRK.           0.
  RANGE ERROR STD. DEV.          19.799 FT.
  AZIMUTH ERROR STD.DEV.          0.036 DEG.

(*)QUALIFIED REPORTS ARE FROM TRACKS THAT:
     - ARE ASSOCIATED WITH 10 OR MORE REPORTS
     - OCCUR AT AN ELEVATION ANGLE BETWEEN .5 AND 40 DEGREES
     - ARE AT A RANGE BETWEEN 2 AND 45 N. MILES
     - CORRESPOND TO AN AIRCRAFT WITH ENCODING ALTIMETER.
```

DABS (TMF)

Fig. III-1(a). Reply processing: Boston, MA (TMF vs ARTS (BI-4)).

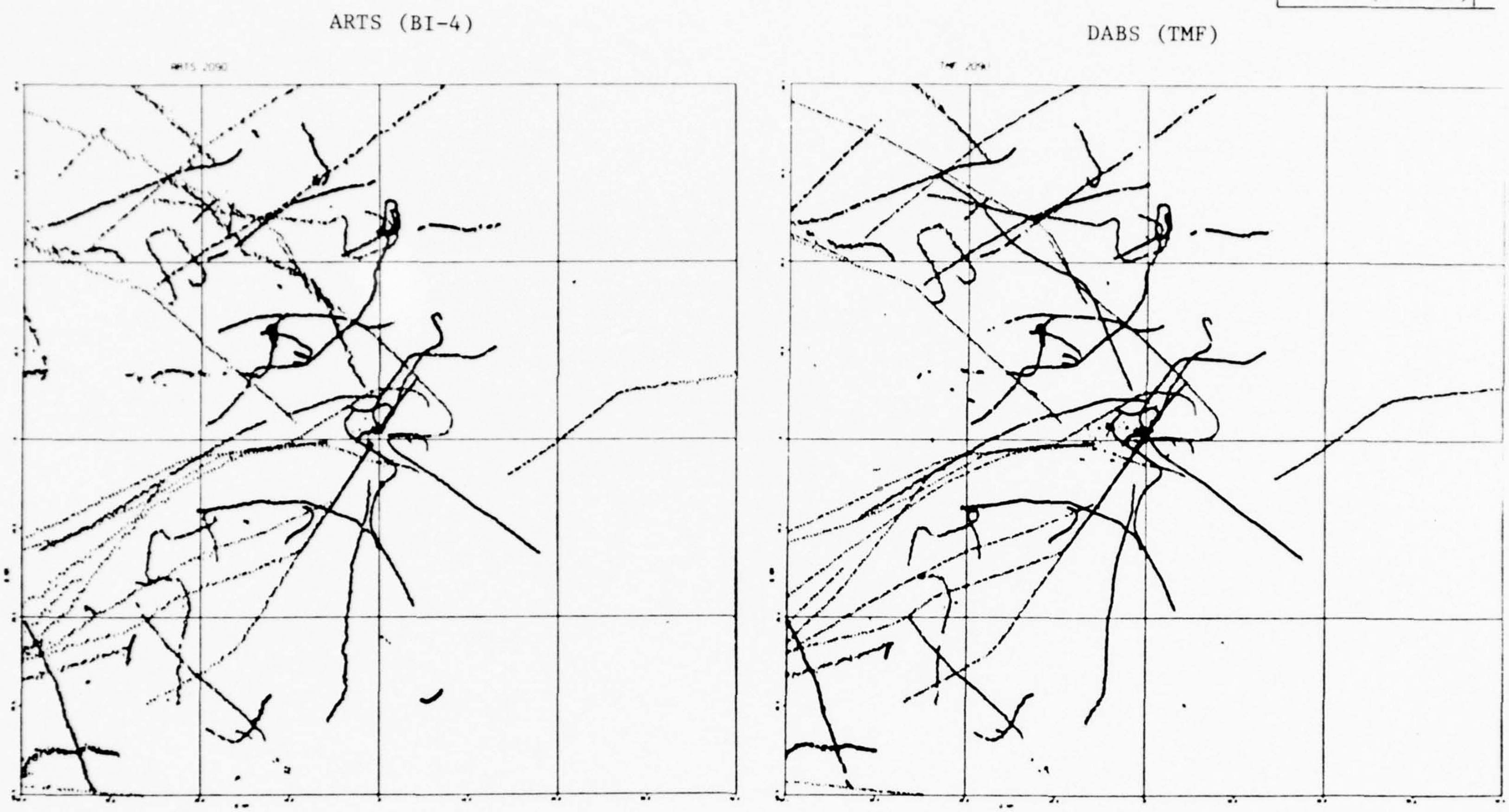


Fig. III-1(b). Traffic flow: Boston, MA (TMF vs ARTS (BI-4)).

4021C

```
                REPLY PROCESSOR
                       |
                       |
                    100. %
                       |
                       |
                 REPORT EDITING
                       |
                       __   0. %  EDITED OUT
                       |
      (  72.82   % ALT.EQUIPPED)
                       |
                       |
     REAL              V                 FALSE
   ______________________________________________
   |                                         |
 99.63 %                                   0.38  %
   |                                         |
 TRACK INITIATION                  TRACK INITIATION
   |                                         |
   |__>  3.59 % _______       0.37 % <__|
   |                   |                     |
   |                DID NOT                  |
   |                START A                  |
   |                 TRACK                   |
   |                                         |
 96.04   %  (MADE REAL          0.01   % (MADE FALSE
   |         TRACKS)                         TRACKS)
   |
   |
   _______________
                  |
                  |
                  V
```

PERFORMANCE SUMMARY FOR 'QUALIFIED' REPORTS(*):

	ALL	CROSSING
BLIP/SCAN	96.0 %	92.0 %
OLD ALTITUDE	3.0 %	9.5 %
OLD CODE	1.2 %	5.9 %
NO. OF QUAL. TRACKS	157.	
TRACK NO. ERROR FRACT.		
2 TRKS ON ONE A/C.	0.0446	
2 A/C ON ONE TRK.	0.0191	
RANGE ERROR STD. DEV.	135.03 FT.	
AZIMUTH ERROR STD.DEV.	0.148 DEG.	

(*) QUALIFIED REPORTS ARE FROM TRACKS THAT:
- ARE ASSOCIATED WITH 10 OR MORE REPORTS
- OCCUR AT AN ELEVATION ANGLE BETWEEN .5 AND 40 DEGREES
- ARE AT A RANGE BETWEEN 2 AND 45 N. MILES
- CORRESPOND TO AN AIRCRAFT WITH ENCODING ALTIMETER.

ARTS (BI-4)

4021T

```
                REPLY PROCESSOR
                       |
                       |
                   108.93 %
                       |
                       |
                 REPORT EDITING
                       |
                       __   8.93 %  EDITED OUT
                       |
      (  72.55   % ALT.EQUIPPED)
                       |
                       |
     REAL              V                 FALSE
   ______________________________________________
   |                                         |
 96.9 %                                    1.09  %
   |                                         |
 TRACK INITIATION                  TRACK INITIATION
   |                                         |
   |__>  3.11 % _______       0.54 % <__|
   |                   |                     |
   |                DID NOT                  |
   |                START A                  |
   |                 TRACK                   |
   |                                         |
 93.79   %  (MADE REAL          0.55   % (MADE FALSE
   |         TRACKS)                         TRACKS)
   |
   |
   _______________
                  |
                  |
                  V
```

PERFORMANCE SUMMARY FOR 'QUALIFIED' REPORTS(*):

	ALL	CROSSING
BLIP/SCAN	97.3 %	96.4 %
OLD ALTITUDE	1.6 %	3.0 %
OLD CODE	1.1 %	4.0 %
NO. OF QUAL. TRACKS	296.	
TRACK NO. ERROR FRACT.		
2 TRKS ON ONE A/C.	0.	
2 A/C ON ONE TRK.	0.0034	
RANGE ERROR STD. DEV.	21.084 FT.	
AZIMUTH ERROR STD.DEV.	0.043 DEG.	

(*) QUALIFIED REPORTS ARE FROM TRACKS THAT:
- ARE ASSOCIATED WITH 10 OR MORE REPORTS
- OCCUR AT AN ELEVATION ANGLE BETWEEN .5 AND 40 DEGREES
- ARE AT A RANGE BETWEEN 2 AND 45 N. MILES
- CORRESPOND TO AN AIRCRAFT WITH ENCODING ALTIMETER.

DABS (TMF)

Fig. III-2(a). Reply processing: Washington, D.C. (TMF vs ARTS (BI-4)).

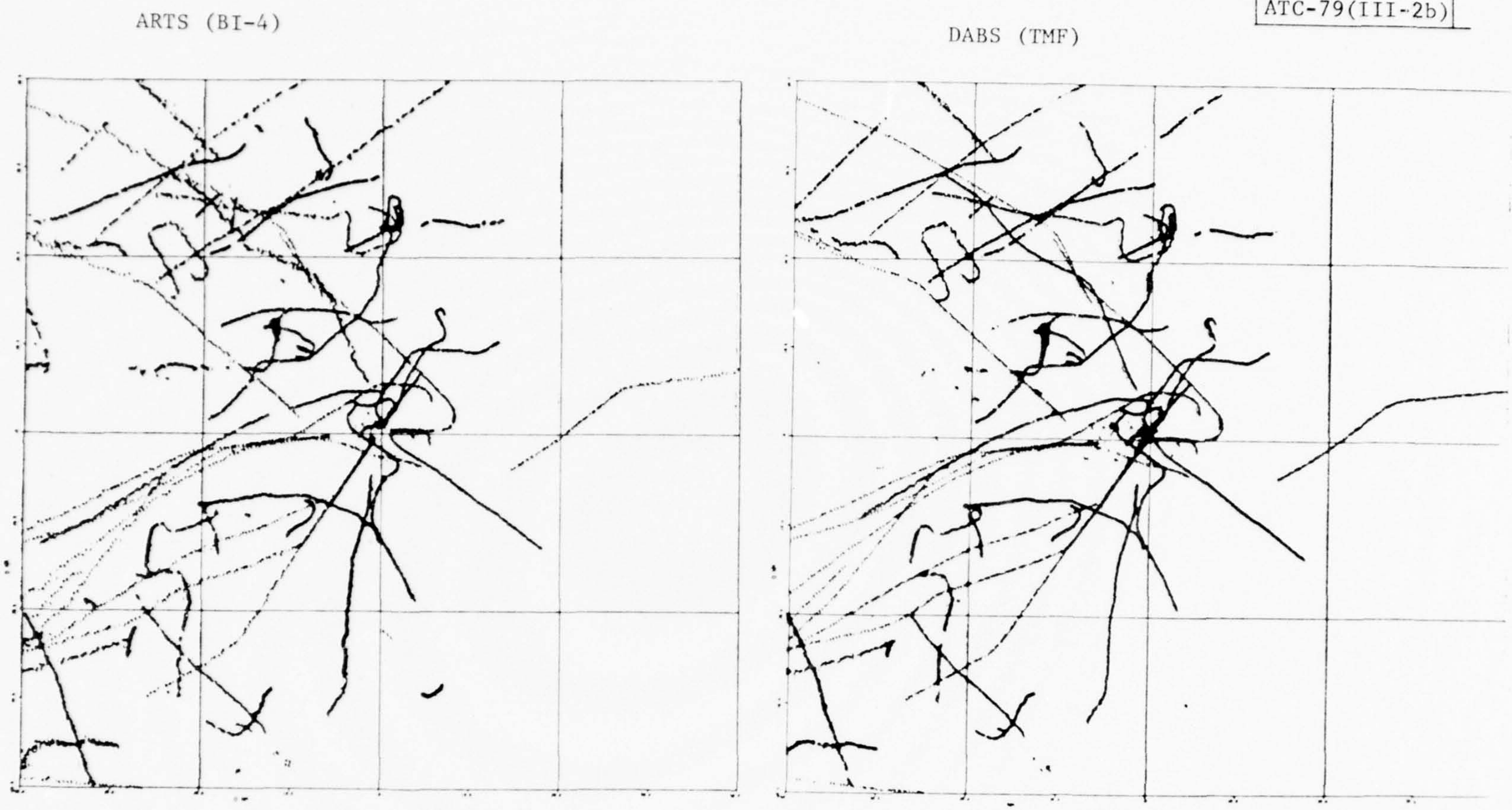


Fig. III-2(b). Traffic flow: Washington, D.C. (TMF vs ARTS (BI-4)).

```
6013C
                     REPLY PROCESSOR
                            |
                            |
                         100. %
                            |
                            |
                      REPORT EDITING
                            |
                            |__   0. %  EDITED OUT
                            |
        ( 56.17  % ALT.EQUIPPED)
                            |
                            |
      REAL                  V                 FALSE
      ---------------------------------------------
      |                                          |
   99.89 %                                     0.1  %
      |                                          |
  TRACK INITIATION                       TRACK INITIATION
      |                                          |
      |__>  4.1 % ________      0.08 % <__|
      |                  |                       |
      |               DID NOT                    |
      |               START A                    |
      |                TRACK                     |
      |                                          V
   95.79  %  (MADE REAL        0.02  % (MADE FALSE
      |       TRACKS)                       TRACKS)
      |
      |
      -----------------
                       |
                       |
                       V
PERFORMANCE SUMMARY FOR 'QUALIFIED' REPORTS(*):

                                   ALL           CROSSING

  BLIP/SCAN                       91.9  %        78.3  %
  OLD ALTITUDE                     3.8  %         6.3  %
  OLD CODE                         2.6  %        11.7  %
  NO. OF QUAL. TRACKS             87.
  TRACK NO. ERROR FRACT.
     2 TRKS ON ONE A/C.            0.069
     2 A/C  ON ONE TRK.            0.0345
  RANGE ERROR STD. DEV.          132.938 FT.
  AZIMUTH ERROR STD.DEV.           0.191 DEG.

(*)QUALIFIED REPORTS ARE FROM TRACKS THAT:
     - ARE ASSOCIATED WITH 10 OR MORE REPORTS
     - OCCUR AT AN ELEVATION ANGLE BETWEEN .5 AND 40 DEGREES
     - ARE AT A RANGE BETWEEN 2 AND 45 N. MILES
     - CORRESPOND TO AN AIRCRAFT WITH ENCODING ALTIMETER.
```

ARTS (BI-4)

```
6013T
                     REPLY PROCESSOR
                            |
                            |
                         111.51 %
                            |
                            |
                      REPORT EDITING
                            |
                            |__   11.51 %  EDITED OUT
                            |
        ( 57.83  % ALT.EQUIPPED)
                            |
                            |
      REAL                  V                 FALSE
      ---------------------------------------------
      |                                          |
   99.58 %                                     0.42  %
      |                                          |
  TRACK INITIATION                       TRACK INITIATION
      |                                          |
      |__>  3.08 % ________      0.25 % <__|
      |                  |                       |
      |               DID NOT                    |
      |               START A                    |
      |                TRACK                     |
      |                                          V
   96.5   %  (MADE REAL        0.17  % (MADE FALSE
      |       TRACKS)                       TRACKS)
      |
      |
      -----------------
                       |
                       |
                       V
PERFORMANCE SUMMARY FOR 'QUALIFIED' REPORTS(*):

                                   ALL           CROSSING

  BLIP/SCAN                       99.4  %        98.6  %
  OLD ALTITUDE                     1.3  %         2.4  %
  OLD CODE                         0.4  %         2.0  %
  NO. OF QUAL. TRACKS            159.
  TRACK NO. ERROR FRACT.
     2 TRKS ON ONE A/C.            0.0126
     2 A/C  ON ONE TRK.            0.0063
  RANGE ERROR STD. DEV.           22.896 FT.
  AZIMUTH ERROR STD.DEV.           0.036 DEG.

(*)QUALIFIED REPORTS ARE FROM TRACKS THAT:
     - ARE ASSOCIATED WITH 10 OR MORE REPORTS
     - OCCUR AT AN ELEVATION ANGLE BETWEEN .5 AND 40 DEGREES
     - ARE AT A RANGE BETWEEN 2 AND 45 N. MILES
     - CORRESPOND TO AN AIRCRAFT WITH ENCODING ALTIMETER.
```

DABS (TMF)

Fig. III-3(a). Reply processing: Philadelphia, PA (TMF vs ARTS (BI-4)).

ARTS (BI-4)

DABS (TMF)

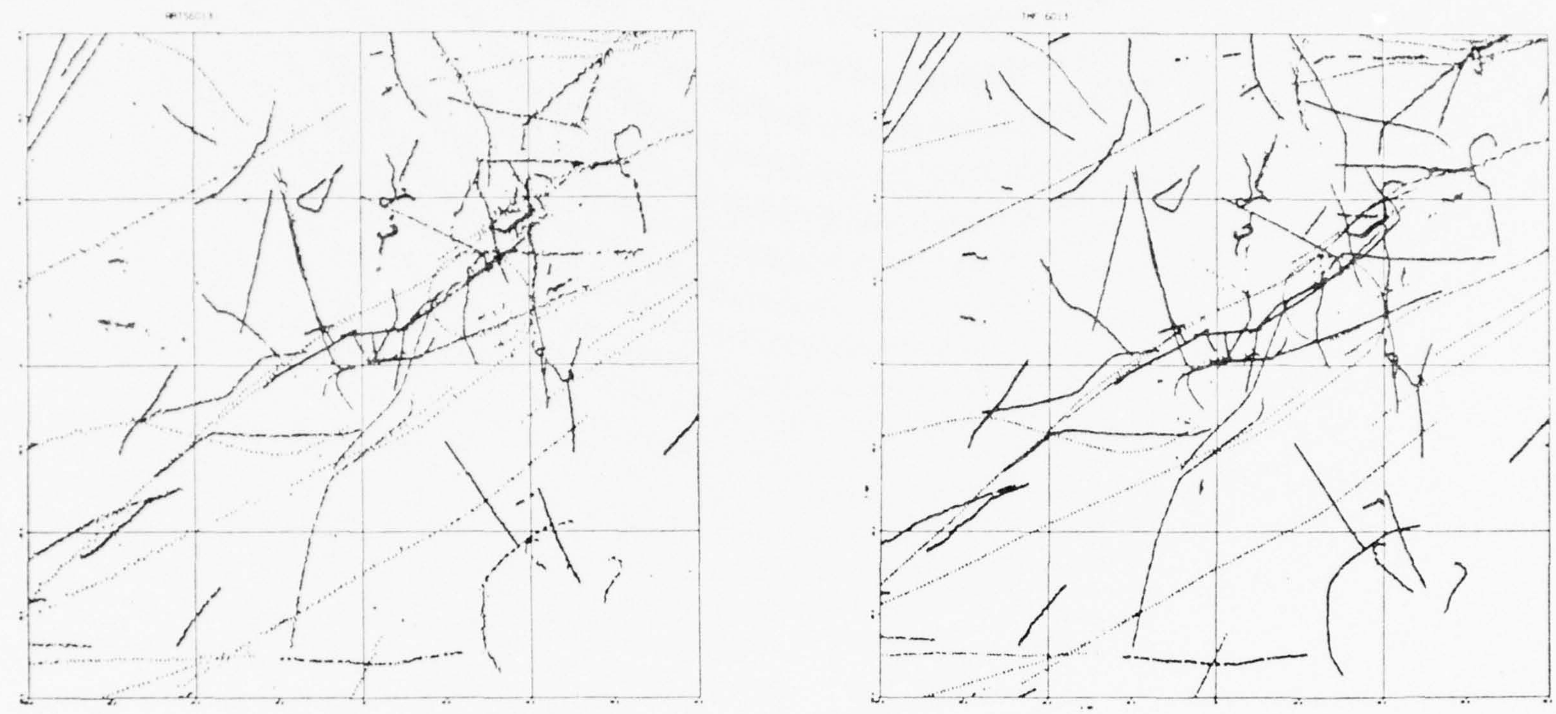


Fig. III-3(b). Traffic flow: Philadelphia, PA (TMF vs ARTS (BI-4)).

7017C

```
                 REPLY PROCESSOR
                       |
                    100. %
                       |
                 REPORT EDITING
                       |
                       __  0. %  EDITED OUT
                       |
            ( 36.94  % ALT.EQUIPPED)
                       |
     REAL              V              FALSE
      ________________________________
      |                               |
   99.53 %                          0.47  %
      |                               |
 TRACK INITIATION              TRACK INITIATION
      |                               |
      |__> 14.08 % ______   0.42 % <__|
      |              |                |
      |           DID NOT             |
      |           START A             |
      |            TRACK              V
   85.45  %  (MADE REAL      0.05  % (MADE FALSE
      |       TRACKS)                    TRACKS)
      |
      ________________
                      |
                      V
```

PERFORMANCE SUMMARY FOR 'QUALIFIED' REPORTS(*):

	ALL	CROSSING
BLIP/SCAN	91.7 %	84.7 %
OLD ALTITUDE	4.2 %	9.5 %
OLD CODE	2.4 %	6.8 %
NO. OF QUAL. TRACKS	74.	
TRACK NO. ERROR FRACT.		
2 TRKS ON ONE A/C.	0.0135	
2 A/C ON ONE TRK.	0.0811	
RANGE ERROR STD. DEV.	99.30 FT.	
AZIMUTH ERROR STD.DEV.	0.143 DEG.	

(*) QUALIFIED REPORTS ARE FROM TRACKS THAT:
- ARE ASSOCIATED WITH 10 OR MORE REPORTS
- OCCUR AT AN ELEVATION ANGLE BETWEEN .5 AND 40 DEGREES
- ARE AT A RANGE BETWEEN 2 AND 45 N. MILES
- CORRESPOND TO AN AIRCRAFT WITH ENCODING ALTIMETER.

ARTS (BI-4)

7017T

```
                 REPLY PROCESSOR
                       |
                    110.32 %
                       |
                 REPORT EDITING
                       |
                       __  10.32 %  EDITED OUT
                       |
            ( 37.31  % ALT.EQUIPPED)
                       |
     REAL              V              FALSE
      ________________________________
      |                               |
   97.84 %                          1.76  %
      |                               |
 TRACK INITIATION              TRACK INITIATION
      |                               |
      |__> 6.72 % ______    0.52 % <__|
      |             |                 |
      |          DID NOT              |
      |          START A              |
      |           TRACK               V
   91.12  %  (MADE REAL      1.24  % (MADE FALSE
      |       TRACKS)                    TRACKS)
      |
      ________________
                      |
                      V
```

PERFORMANCE SUMMARY FOR 'QUALIFIED' REPORTS(*):

	ALL	CROSSING
BLIP/SCAN	96.7 %	94.7 %
OLD ALTITUDE	1.4 %	3.0 %
OLD CODE	0.8 %	2.1 %
NO. OF QUAL. TRACKS	142.	
TRACK NO. ERROR FRACT.		
2 TRKS ON ONE A/C.	0.0141	
2 A/C ON ONE TRK.	0.0211	
RANGE ERROR STD. DEV.	41.54 FT.	
AZIMUTH ERROR STD.DEV.	0.059 DEG.	

(*) QUALIFIED REPORTS ARE FROM TRACKS THAT:
- ARE ASSOCIATED WITH 10 OR MORE REPORTS
- OCCUR AT AN ELEVATION ANGLE BETWEEN .5 AND 40 DEGREES
- ARE AT A RANGE BETWEEN 2 AND 45 N. MILES
- CORRESPOND TO AN AIRCRAFT WITH ENCODING ALTIMETER.

DABS (TMF)

Fig. III-4(a). Reply processing: Los Angeles, CA (TMF vs ARTS (BI-4)).

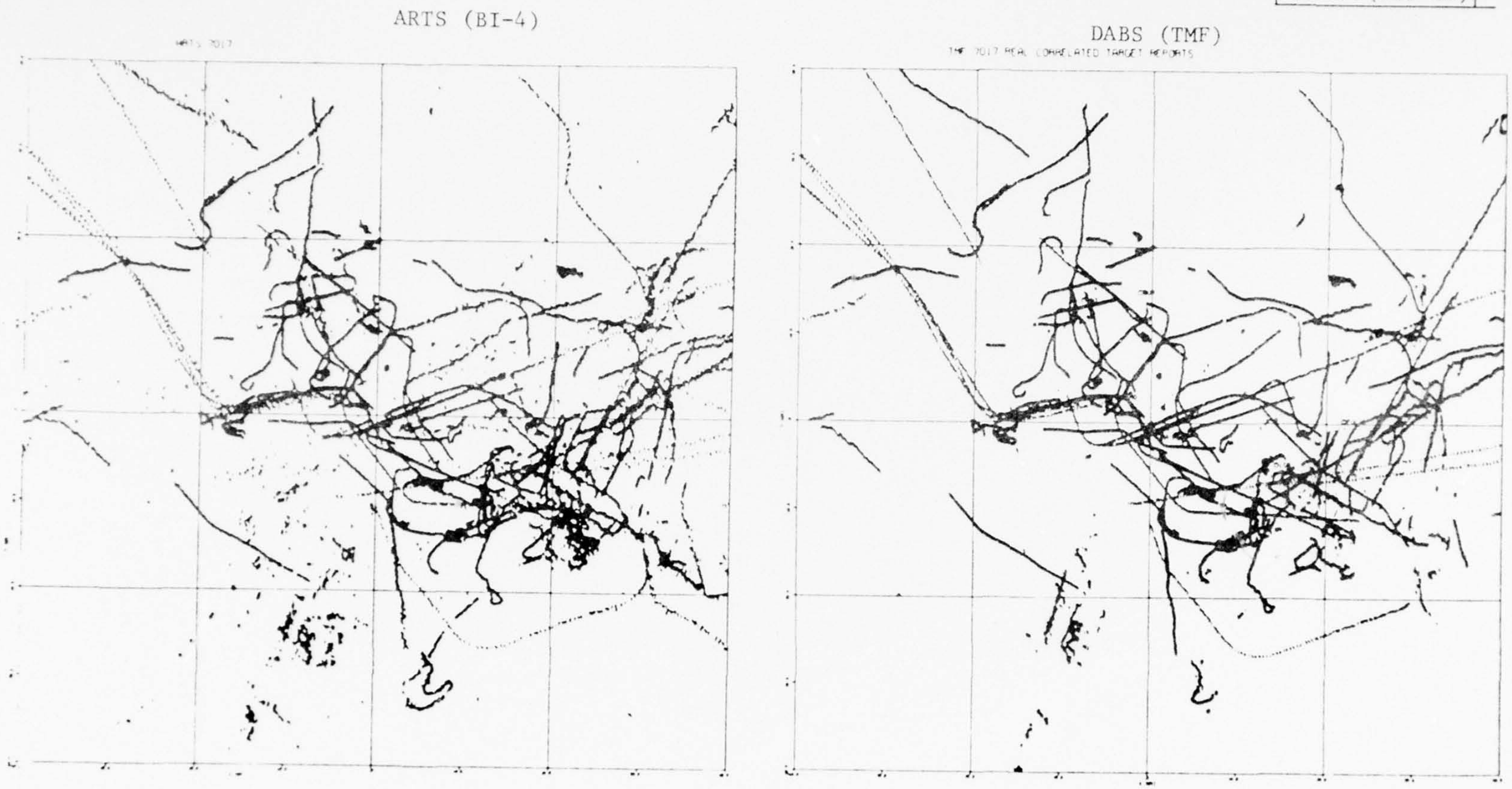
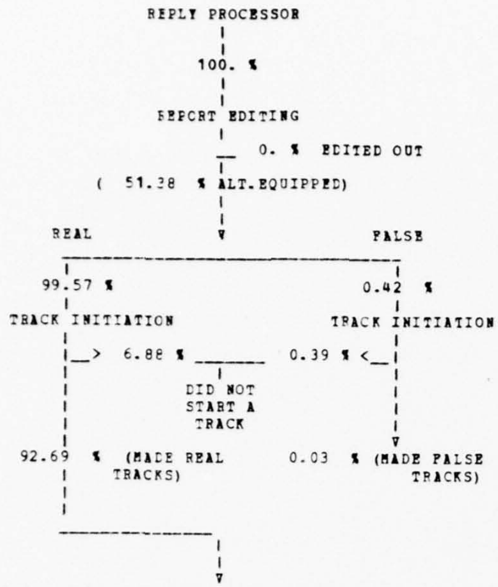


Fig. III-4(b). Traffic flow: Los Angeles, CA (TMF vs ARTS (BI-4)).

9005C



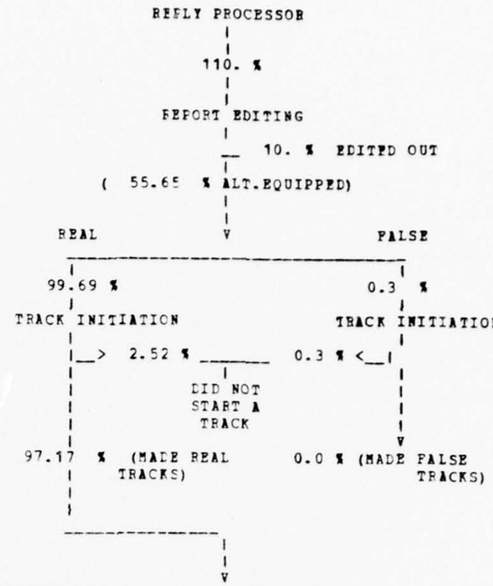
PERFORMANCE SUMMARY FOR 'QUALIFIED' REPORTS(*):

	ALL	CROSSING
BLIP/SCAN	93.0 %	75.4 %
OLD ALTITUDE	3.3 %	12.2 %
OLD CODE	1.0 %	7.1 %
NO. OF QUAL. TRACKS	23.	
TRACK NO. ERROR FRACT.		
2 TRKS ON ONE A/C.	0.0435	
2 A/C ON ONE TRK.	0.	
RANGE ERROR STD. DEV.	109.039 FT.	
AZIMUTH ERROR STD.DEV.	0.236 DEG.	

(*)QUALIFIED REPORTS ARE FROM TRACKS THAT:
- ARE ASSOCIATED WITH 10 OR MORE REPORTS
- OCCUR AT AN ELEVATION ANGLE BETWEEN .5 AND 40 DEGREES
- ARE AT A RANGE BETWEEN 2 AND 45 N. MILES
- CORRESPOND TO AN AIRCRAFT WITH ENCODING ALTIMETER.

ARTS (BI-4)

9005T



PERFORMANCE SUMMARY FOR 'QUALIFIED' REPORTS(*):

	ALL	CROSSING
BLIP/SCAN	98.0 %	95.0 %
OLD ALTITUDE	0.8 %	8.8 %
OLD CODE	0.8 %	7.0 %
NO. OF QUAL. TRACKS	28.	
TRACK NO. ERROR FRACT.		
2 TRKS ON ONE A/C.	0.	
2 A/C ON ONE TRK.	0.	
RANGE ERROR STD. DEV.	20.065 FT.	
AZIMUTH ERROR STD.DEV.	0.033 DEG.	

(*)QUALIFIED REPORTS ARE FROM TRACKS THAT:
- ARE ASSOCIATED WITH 10 OR MORE REPORTS
- OCCUR AT AN ELEVATION ANGLE BETWEEN .5 AND 40 DEGREES
- ARE AT A RANGE BETWEEN 2 AND 45 N. MILES
- CORRESPOND TO AN AIRCRAFT WITH ENCODING ALTIMETER.

DABS (TMF)

Fig. III-5(a). Reply processing: Salt Lake City, UT (TMF vs ARTS (BI-4)).

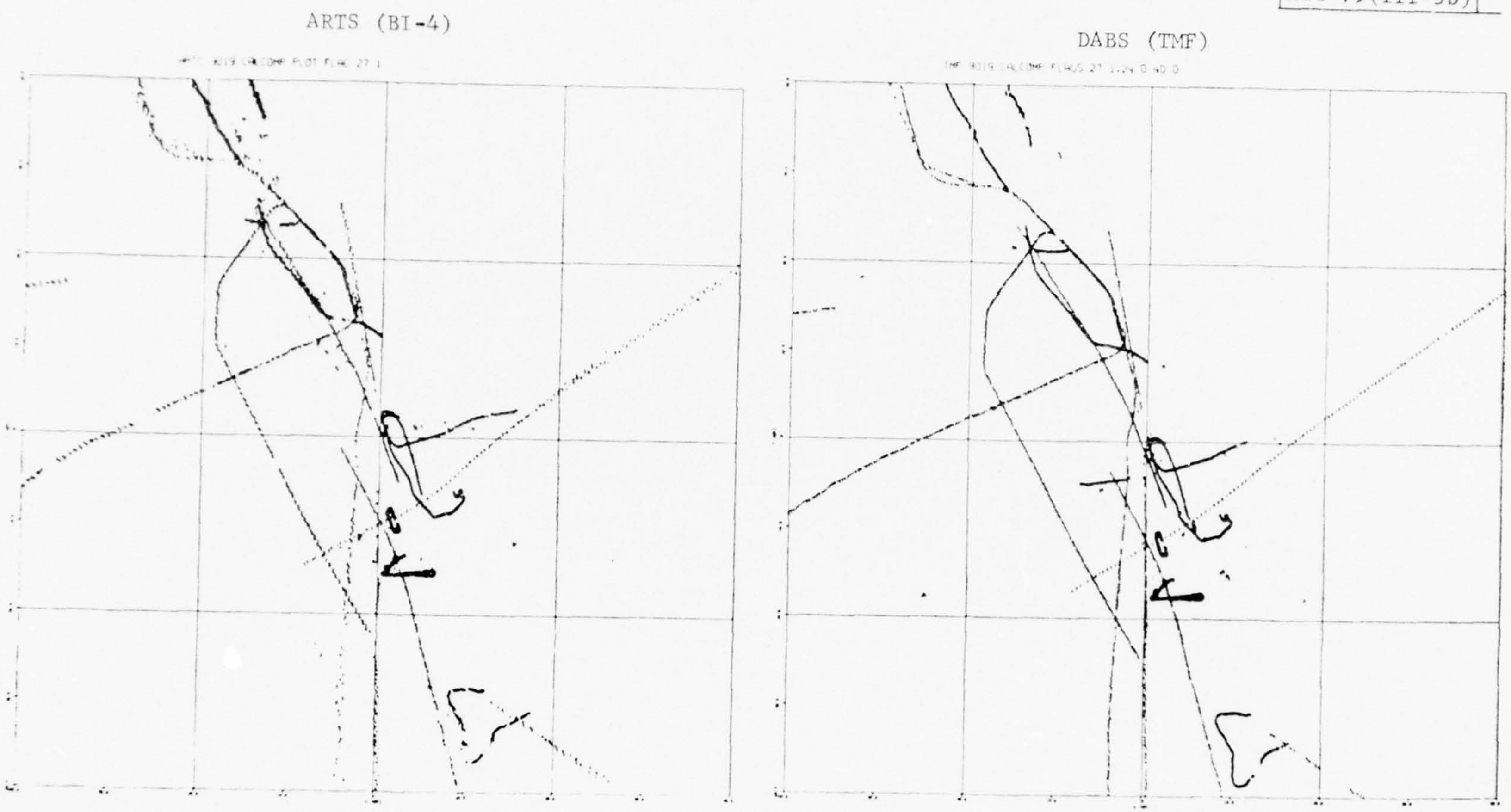


Fig. III-5(b). Traffic flow: Salt Lake City, UT (TMF vs ARTS (BI-4)).

```
11010C
                         REPLY PROCESSOR
                               |
                             100. %
                               |
                         REPORT EDITING
                               |
                               |__  0. %  EDITED OUT
                               |
               ( 55.25  % ALT.EQUIPPED)
                               |
        REAL                   V              FALSE
         ________________________________________
         |                                      |
       99.93 %                               0.06  %
         |                                      |
   TRACK INITIATION                    TRACK INITIATION
         |                                      |
         |__>  1.85 %  _______    0.06 % <__|
         |                |                     |
         |             DID NOT                  |
         |             START A                  |
         |              TRACK                   |
         |                                      V
       98.08  %  (MADE REAL          0.0 % (MADE FALSE
         |        TRACKS)                       TRACKS)
         |
         |______________
                        |
                        |
                        V
```

PERFORMANCE SUMMARY FOR 'QUALIFIED' REPORTS(*):

	ALL	CROSSING
BLIP/SCAN	94.3 %	85.5 %
OLD ALTITUDE	1.2 %	8.7 %
OLD CODE	0.8 %	8.2 %
NO. OF QUAL. TRACKS	64.	
TRACK NO. ERROR FRACT.		
2 TRKS ON ONE A/C.	0.	
2 A/C ON ONE TRK.	0.0313	
RANGE ERROR STD. DEV.	102.526 FT.	
AZIMUTH ERROR STD.DEV.	0.129 DEG.	

(*) QUALIFIED REPORTS ARE FROM TRACKS THAT:
- ARE ASSOCIATED WITH 10 OR MORE REPORTS
- OCCUR AT AN ELEVATION ANGLE BETWEEN .5 AND 40 DEGREES
- ARE AT A RANGE BETWEEN 2 AND 45 N. MILES
- CORRESPOND TO AN AIRCRAFT WITH ENCODING ALTIMETER.

ARTS (BI-4)

```
11010T
                         REPLY PROCESSOR
                               |
                            106.26 %
                               |
                         REPORT EDITING
                               |
                               |__  6.26 %  EDITED OUT
                               |
               ( 59.08  % ALT.EQUIPPED)
                               |
        REAL                   V              FALSE
         ________________________________________
         |                                      |
       99.76 %                               0.24  %
         |                                      |
   TRACK INITIATION                    TRACK INITIATION
         |                                      |
         |__>  2.54 %  _______    0.24 % <__|
         |                |                     |
         |             DID NOT                  |
         |             START A                  |
         |              TRACK                   |
         |                                      V
       97.22  %  (MADE REAL          0.0 % (MADE FALSE
         |        TRACKS)                       TRACKS)
         |
         |______________
                        |
                        |
                        V
```

PERFORMANCE SUMMARY FOR 'QUALIFIED' REPORTS(*):

	ALL	CROSSING
BLIP/SCAN	98.5 %	95.2 %
OLD ALTITUDE	1.6 %	4.0 %
OLD CODE	0.3 %	3.0 %
NO. OF QUAL. TRACKS	130.	
TRACK NO. ERROR FRACT.		
2 TRKS ON ONE A/C.	0.	
2 A/C ON ONE TRK.	0.	
RANGE ERROR STD. DEV.	24.037 FT.	
AZIMUTH ERROR STD.DEV.	0.036 DEG.	

(*) QUALIFIED REPORTS ARE FROM TRACKS THAT:
- ARE ASSOCIATED WITH 10 OR MORE REPORTS
- OCCUR AT AN ELEVATION ANGLE BETWEEN .5 AND 40 DEGREES
- ARE AT A RANGE BETWEEN 2 AND 45 N. MILES
- CORRESPOND TO AN AIRCRAFT WITH ENCODING ALTIMETER.

DABS TMF

Fig. III-6(a). Reply processing: Las Vegas, NV (TMF vs ARTS (BI-4)).

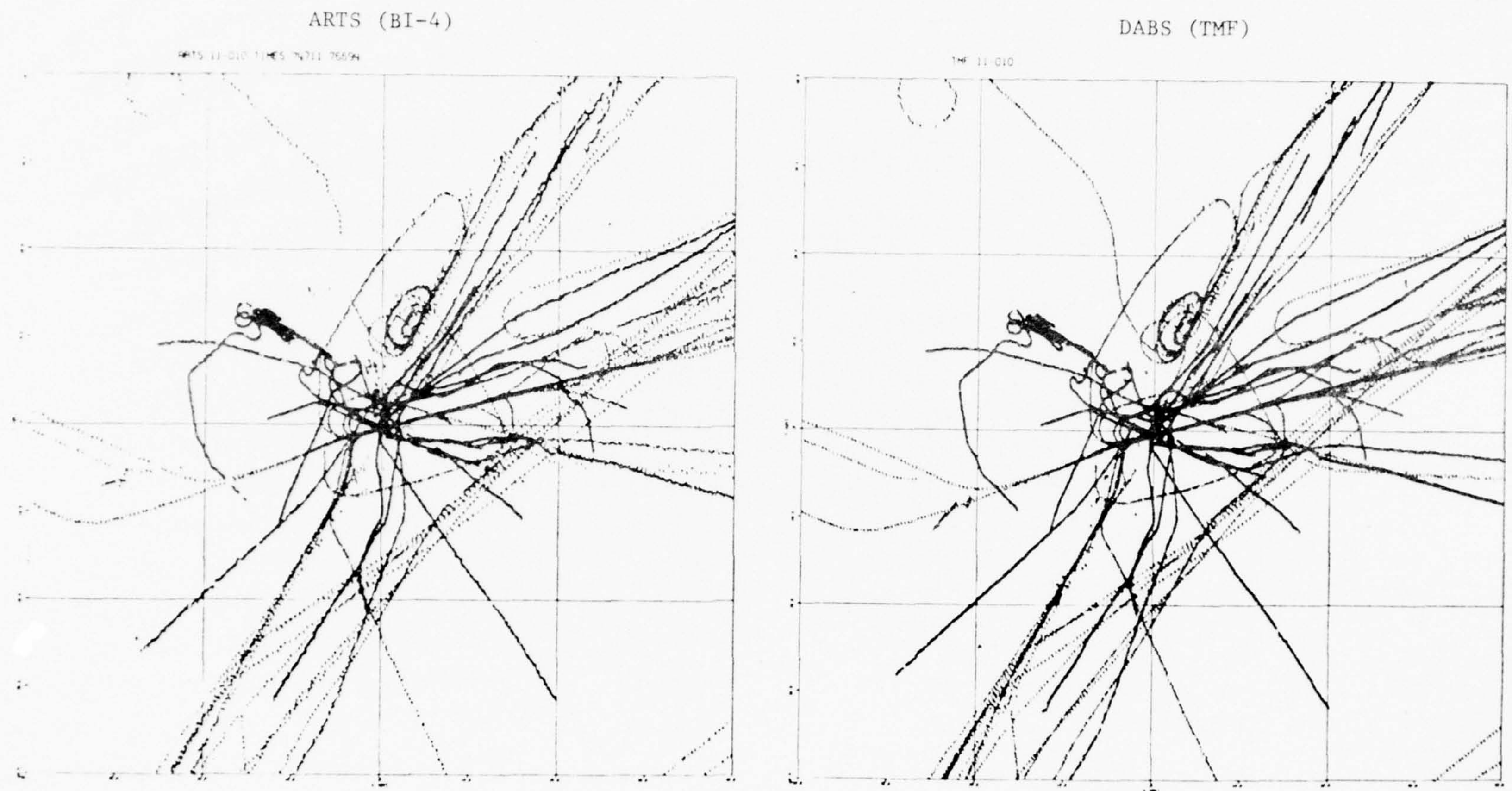


Fig. III-6(b). Traffic flow: Las Vegas, NV (TMF vs ARTS (BI-4)).

ATC-79(III-7)

```
COMBC

                    REPLY PROCESSOR
                          |
                        100. %
                          |
                    REPORT EDITING
                          |
                          |__ 0. % EDITED OUT
                          |
       ( 60.32            % ALT.EQUIPPED)
                          |
                          |
     REAL                 V                FALSE
      ____________________________________
      |                                    |
    99.74   %                            0.27   %
      |                                    |
  TRACK INITIATION                  TRACK INITIATION
      |                                    |
      |__> 4.68% _______    0.25    % <__|
      |               |                    |
      |            DID NOT                 |
      |            START A                 |
      |             TRACK                  |
      |                                    V
  95.05     % (MADE REAL       0.02      % (MADE FALSE
      |       TRACKS)                      TRACKS)
      |
      |_______________
                      |
                      |
                      V
PERFORMANCE SUMMARY FOR 'QUALIFIED' REPORTS(*):

                               ALL             CROSSING

BLIP/SCAN                     94.55   %         86.86   %
OLD ALTITUDE                   2.72   %          8.34   %
OLD CODE                       1.45   %          7.41   %
NO. OF QUAL. TRACKS          102.
TRACK NO. ERROR FRACT.
   2 TRKS ON ONE A/C.          0.0415
   2 A/C  ON ONE TRK.          0.028
RANGE ERROR STD. DEV.        123.88   FT.
AZIMUTH ERROR STD.DEV.         0.16   DEG.

(*)QUALIFIED REPORTS ARE FROM TRACKS THAT:
   - ARE ASSOCIATED WITH 10 OR MORE REPORTS
   - OCCUR AT AN ELEVATION ANGLE BETWEEN .5 AND 40 DEGREES
   - ARE AT A RANGE BETWEEN 2 AND 45 N. MILES
   - CORRESPOND TO AN AIRCRAFT WITH ENCODING ALTIMETER.
```

ARTS (BI-4)

```
COMBU

                    REPLY PROCESSOR
                          |
                       109.30 %
                          |
                    REPORT EDITING
                          |
                          |__ 9.30 % EDITED OUT
                          |
       ( 61.9213          % ALT.EQUIPPED)
                          |
                          |
     REAL                 V                FALSE
      ____________________________________
      |                                    |
    98.38   %                            0.78   %
      |                                    |
  TRACK INITIATION                  TRACK INITIATION
      |                                    |
      |__> 3.40% _______    0.40    % <__|
      |               |                    |
      |            DID NOT                 |
      |            START A                 |
      |             TRACK                  |
      |                                    V
  94.98     % (MADE REAL       0.38      % (MADE FALSE
      |       TRACKS)                      TRACKS)
      |
      |_______________
                      |
                      |
                      V
PERFORMANCE SUMMARY FOR 'QUALIFIED' REPORTS(*):

                               ALL             CROSSING

BLIP/SCAN                     97.99   %         96.63   %
OLD ALTITUDE                   1.39   %          3.04   %
OLD CODE                       0.68   %          3.01   %
NO. OF QUAL. TRACKS          192.
TRACK NO. ERROR FRACT.
   2 TRKS ON ONE A/C.          0.0051
   2 A/C  ON ONE TRK.          0.0045
RANGE ERROR STD. DEV.         23.88   FT.
AZIMUTH ERROR STD.DEV.         0.04   DEG.

(*)QUALIFIED REPORTS ARE FROM TRACKS THAT:
   - ARE ASSOCIATED WITH 10 OR MORE REPORTS
   - OCCUR AT AN ELEVATION ANGLE BETWEEN .5 AND 40 DEGREES
   - ARE AT A RANGE BETWEEN 2 AND 45 N. MILES
   - CORRESPOND TO AN AIRCRAFT WITH ENCODING ALTIMETER.
```

DABS (TMF)

Fig. III-7. Reply processing: average site (TMF vs ARTS (BI-4)).

IV. SITE-TO-SITE STATISTICS

One of the objectives of the TMF field tests was to determine if DABS would work well in many different site/traffic environments. It was noted in the last section that there was a general similarity in the effect of site on both TMF and ARTS (BI-4) data. In this section the statistics of the total sample of TMF experiments (54) run at all sites (11) are examined and the causes for differences considered.

A. Altimeter Equipage

Figure IV-1 shows the percentage of aircraft seen by the TMF that had operating encoding altimeters. This is not a performance feature of the TMF but is an interesting statistic on the aircraft population. The percentage varies from about 45% in the Los Angeles area to over 70% at Washington, D.C. and Clementon, N.J. At Clementon, several runs at long range were taken and thus a high percentage of high flying air carriers along the East Coast could be seen.

B. Blip/Scan Ratio

The TMF blip/scan ratio is shown in Fig. IV-2 for all qualified tracks. Most data are 98% or greater. In crossing track situations, Fig. IV-3, the blip scan ratio declined 2 to 4 percentage points.

C. Old Altitude (No altitude update this scan)

Fig. IV-4 shows the percent of reports sent out by the DABS sensor which did not have an altitude update this scan. Fig. IV-5 shows the same item for crossing track situations where the percentage generally increases (double, or more in most cases).

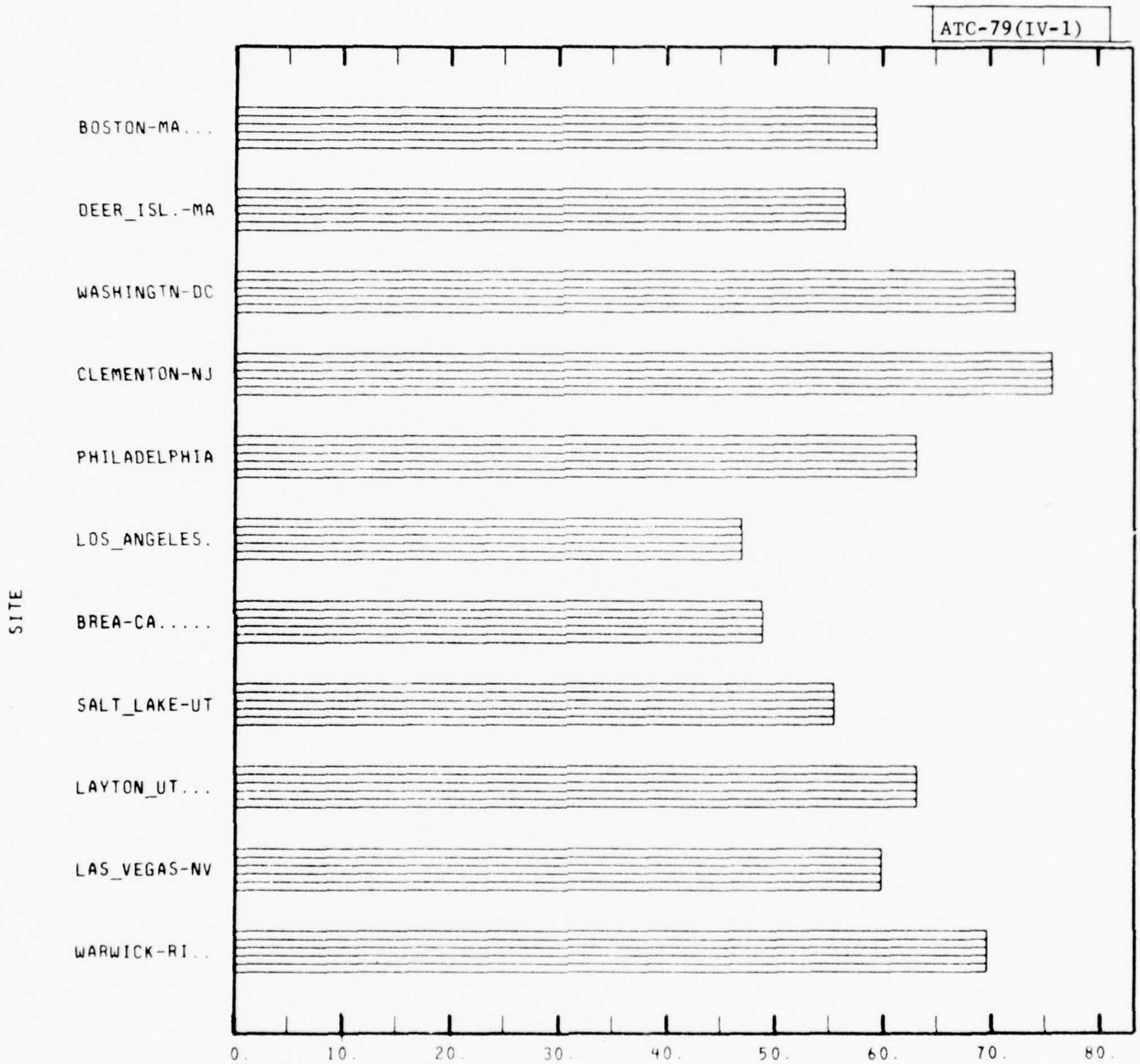


Fig. IV-1. Aircraft with encoding altimeters (percent of ATCRBS equipped aircraft).

ATC-79(IV-2)

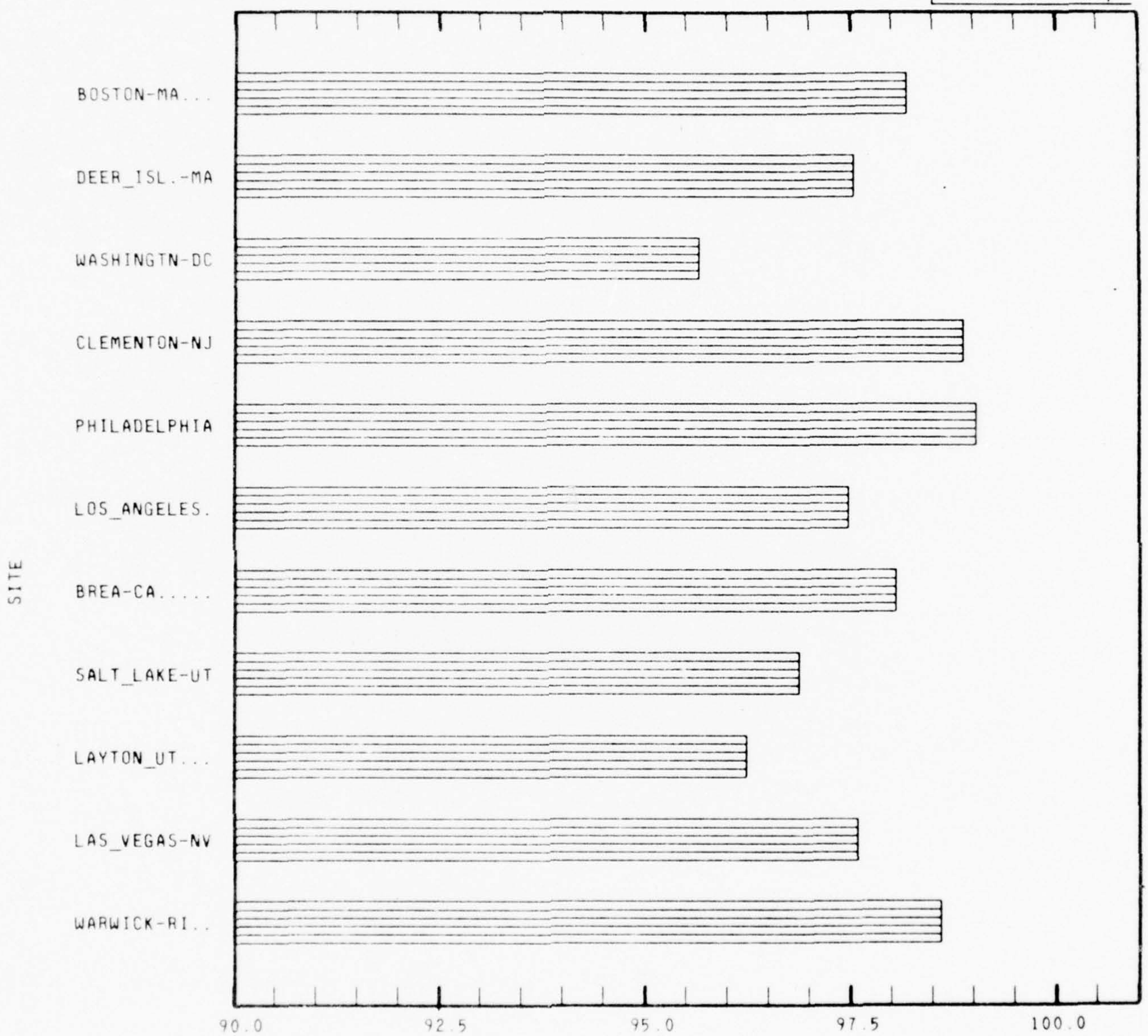


Fig. IV-2. Blip/scan ratio (all tracks; percent).

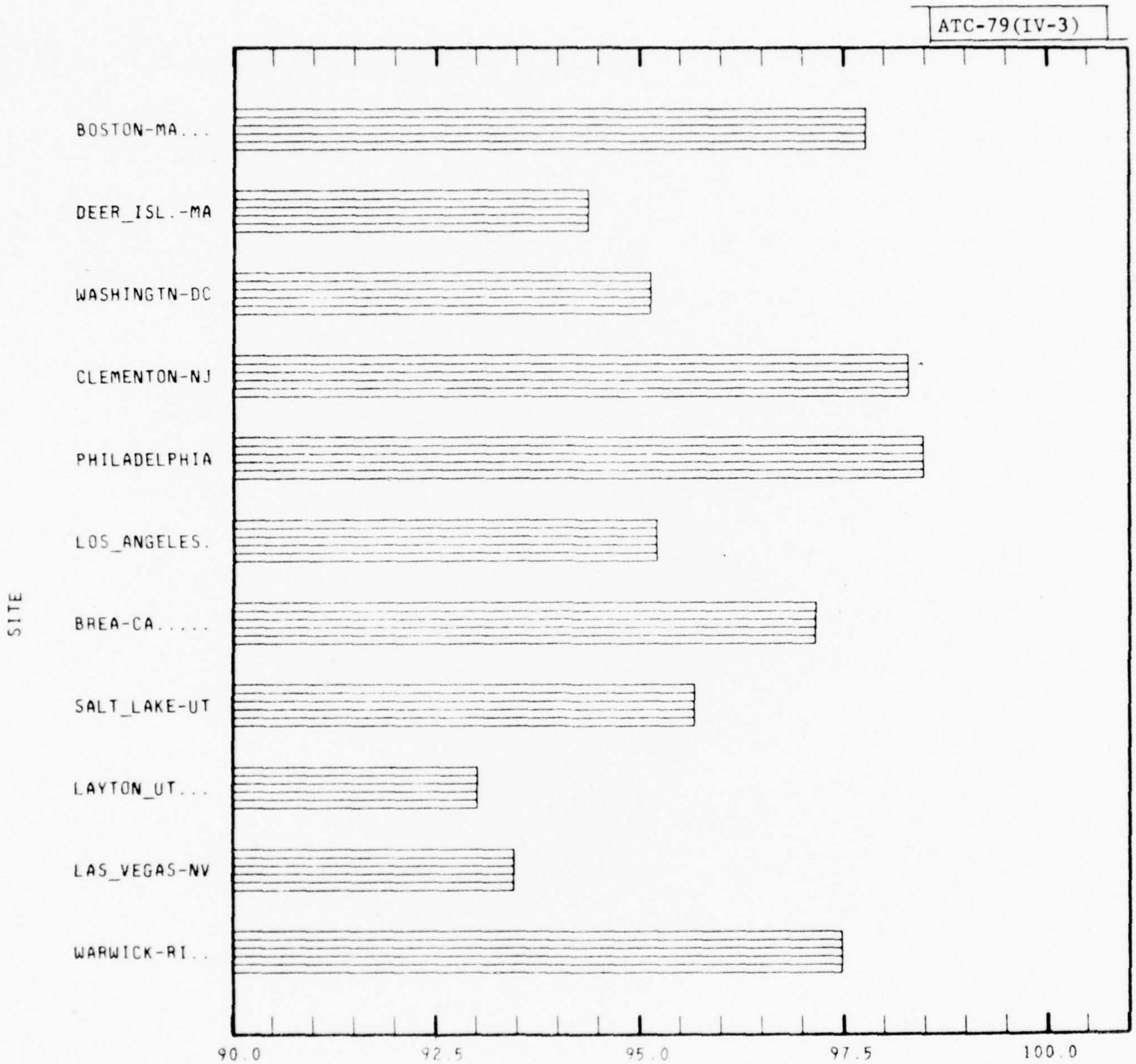


Fig. IV-3. Blip/scan ratio (crossing tracks; percent).

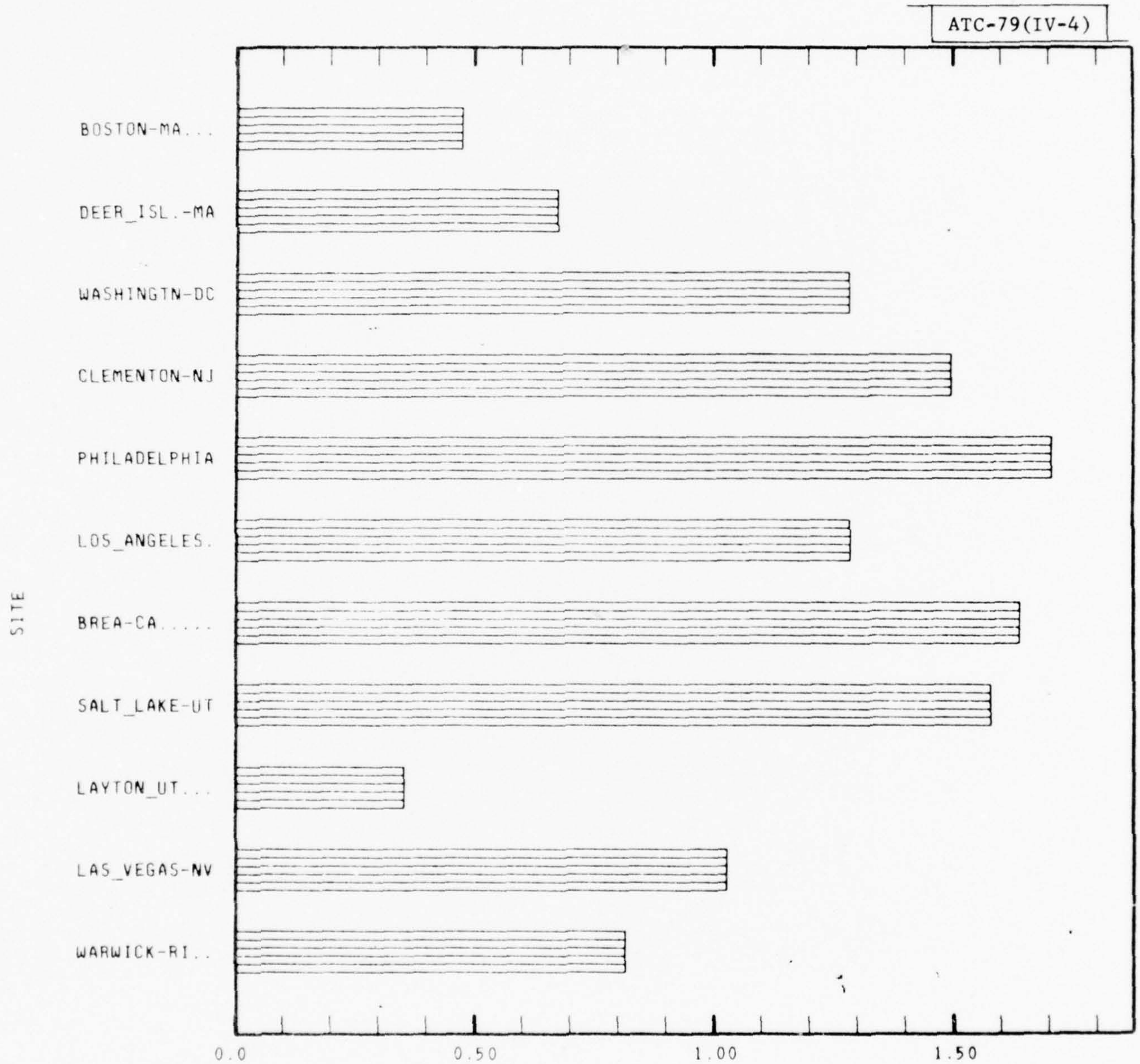


Fig. IV-4. Reports without altitude update this scan (all tracks; percent).

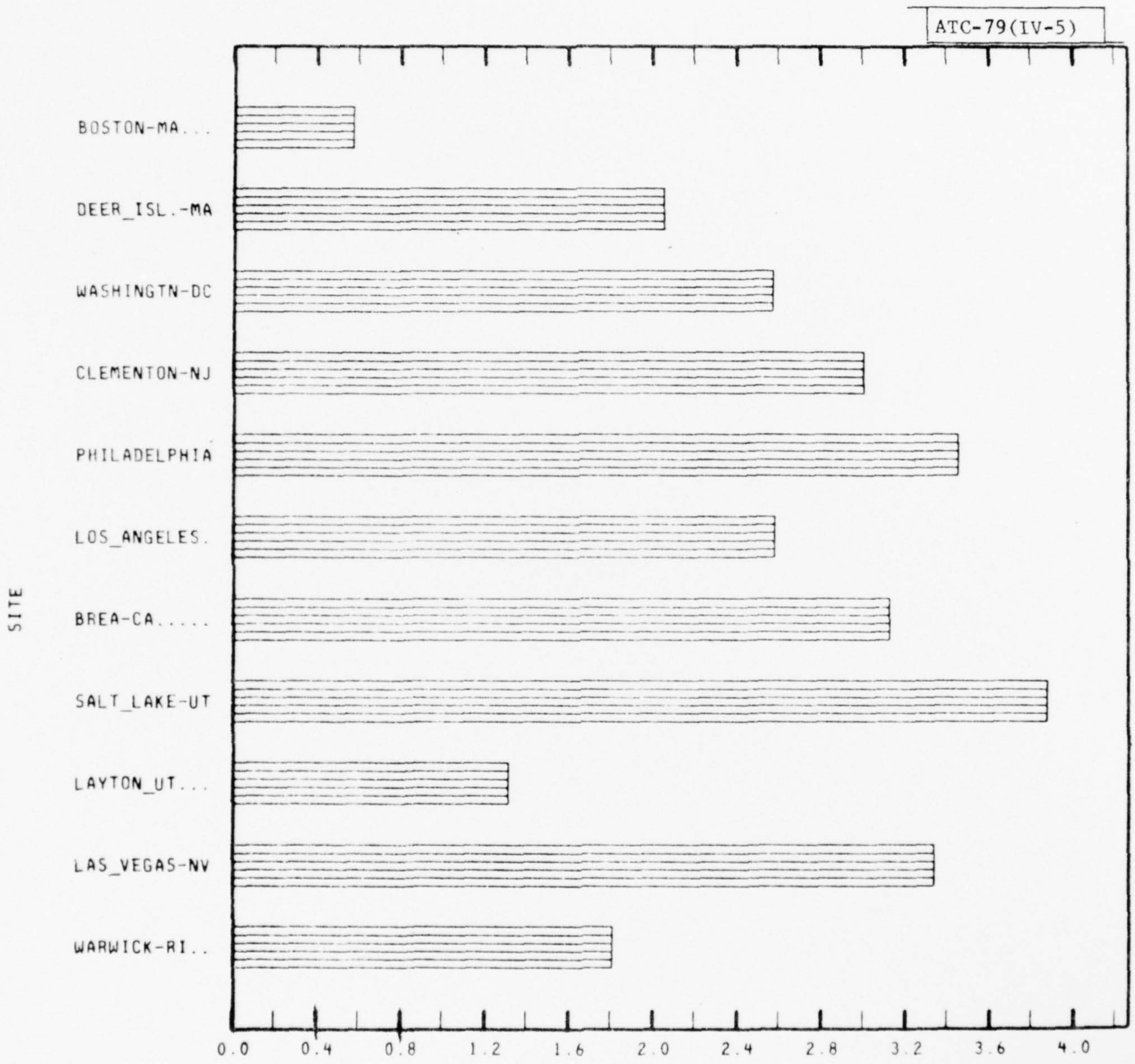


Fig. IV-5. Reports without altitude update this scan (crossing tracks; percent).

Note that not updating an altitude each scan is not necessarily a system error. The only time an error occurs because of this is when the aircraft changes altitude while the track altitude is being coasted.

D. Old Code (no code update this scan)

Figures IV-6 and IV-7 show the percent of reports which did not have a current updated code. Figure IV-7 is a subset of Fig. IV-6, showing only those reports in crossing track situations. For crossing tracks, the percent of old codes just about trebles.

E. Track Number Errors

The number of "2 tracks on one aircraft" and "2 aircraft on one track", track errors expressed as a fraction of the total number of qualified tracks (Fig. IV-8) occurring during the duration of the test, are shown in Fig. IV-9 and Fig. IV-10.

F. Range Error

The standard deviation of range error (representative of both DABS and ATCRBS mode performance) is shown in Fig. IV-11. Range error is seen to be quite uniform for all sites except for Los Angeles. This may have been due to the fact that in Los Angeles (and in Brea) a very long pulse was received frequently causing buffer overflow. The ARTS has also seen this effect, but the source has not been located.

G. Azimuth Error

The monopulse azimuth error is specified in the DABS Sensor Engineering Requirement to be 0.1°. This is to be met under the worst case fruit environment to be seen until 1995. In the absence of this much fruit, the mono-

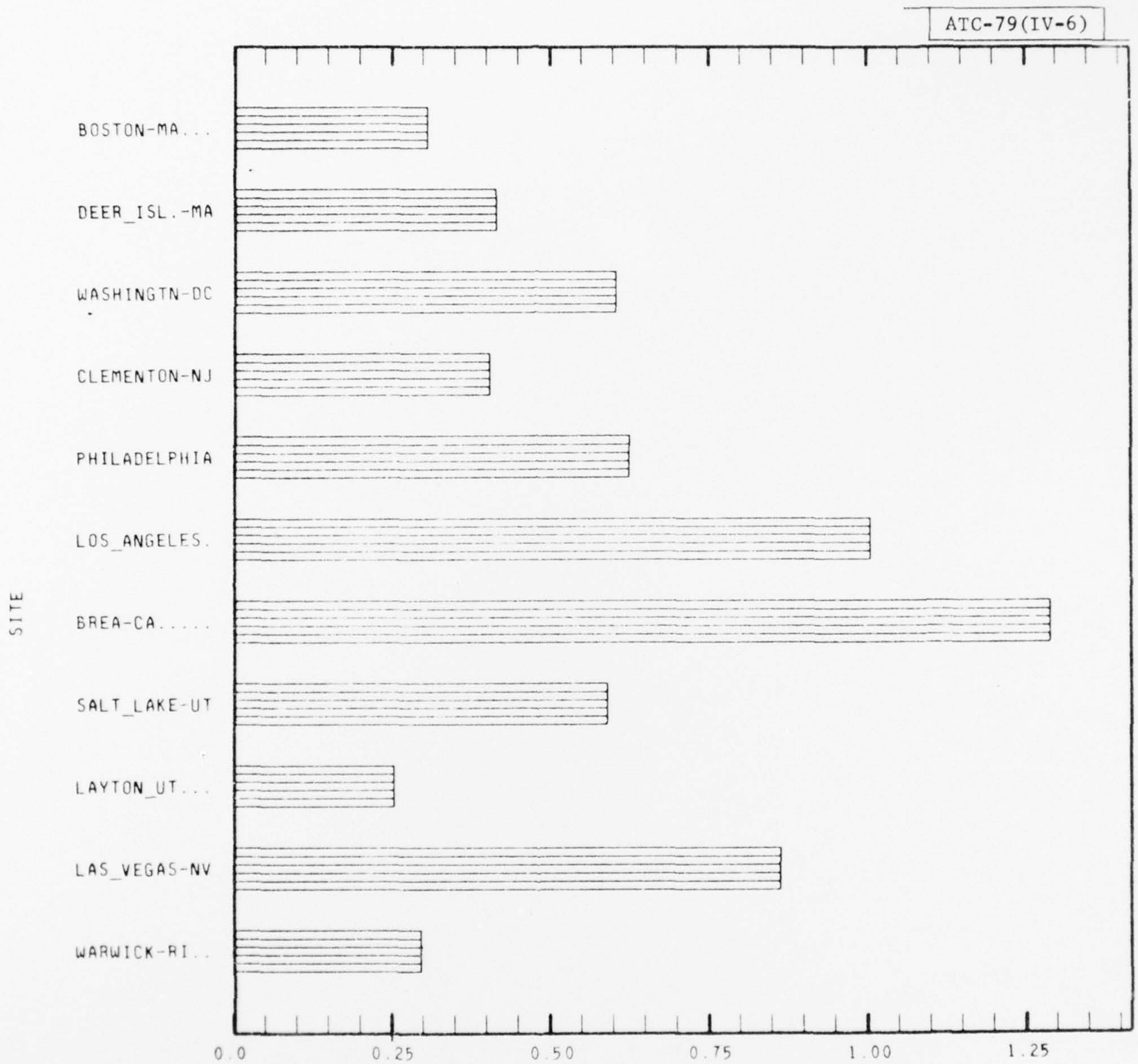


Fig. IV-6. Reports without code update this scan (all tracks; percent).

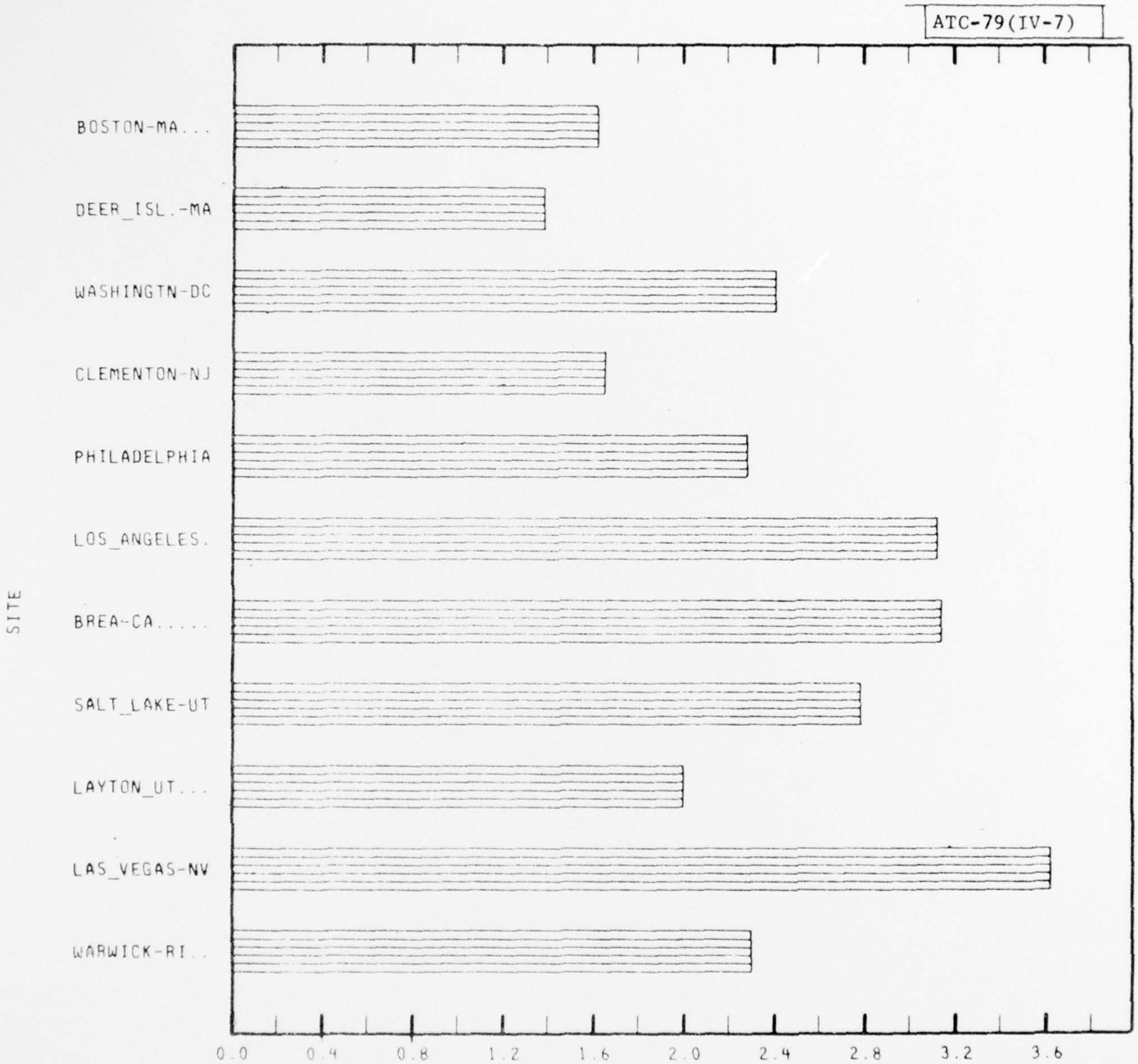


Fig. IV-7. Reports without code update this scan (crossing tracks; percent).

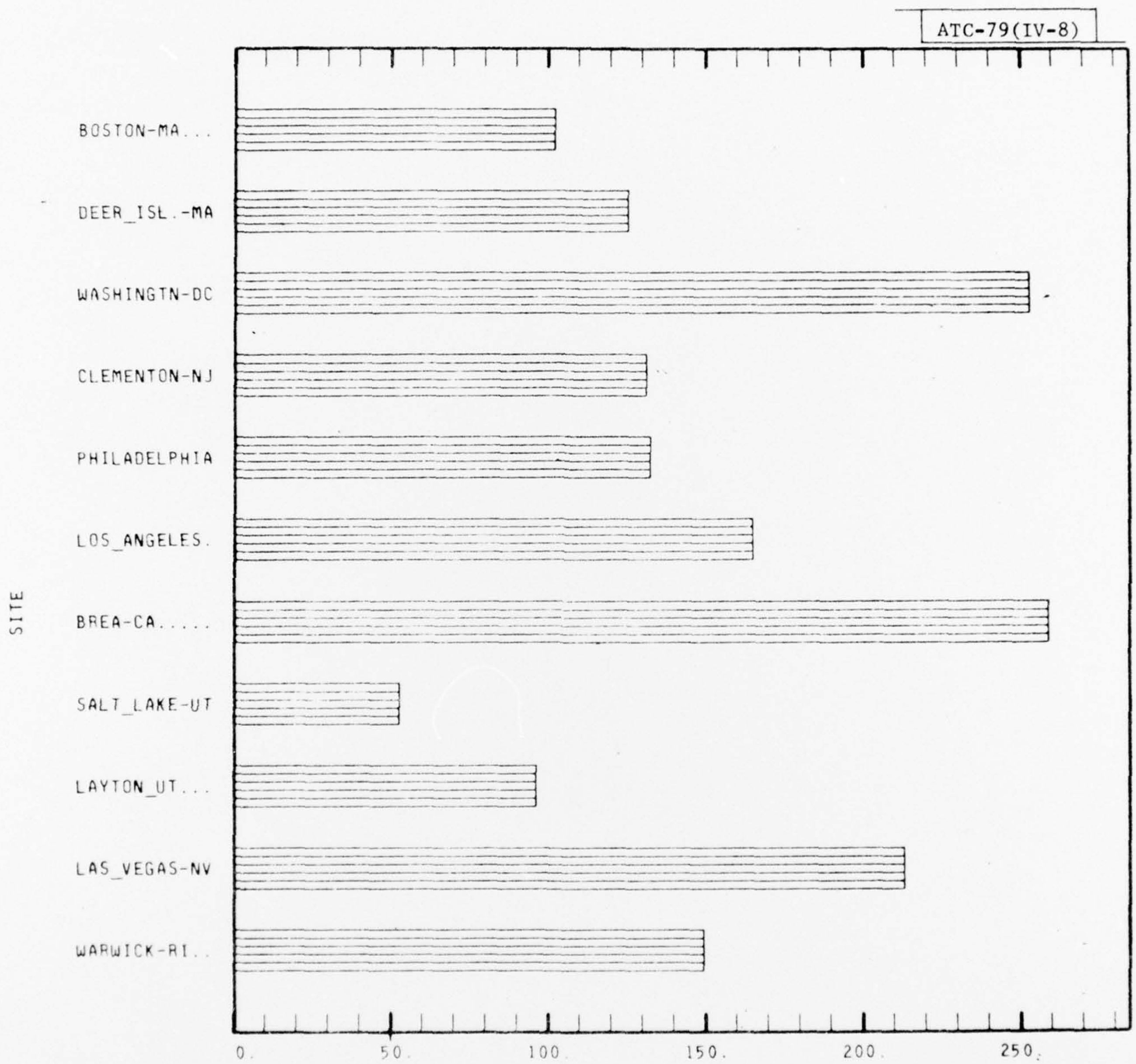


Fig. IV-8. Number of qualified tracks.

ATC-79(IV-9)

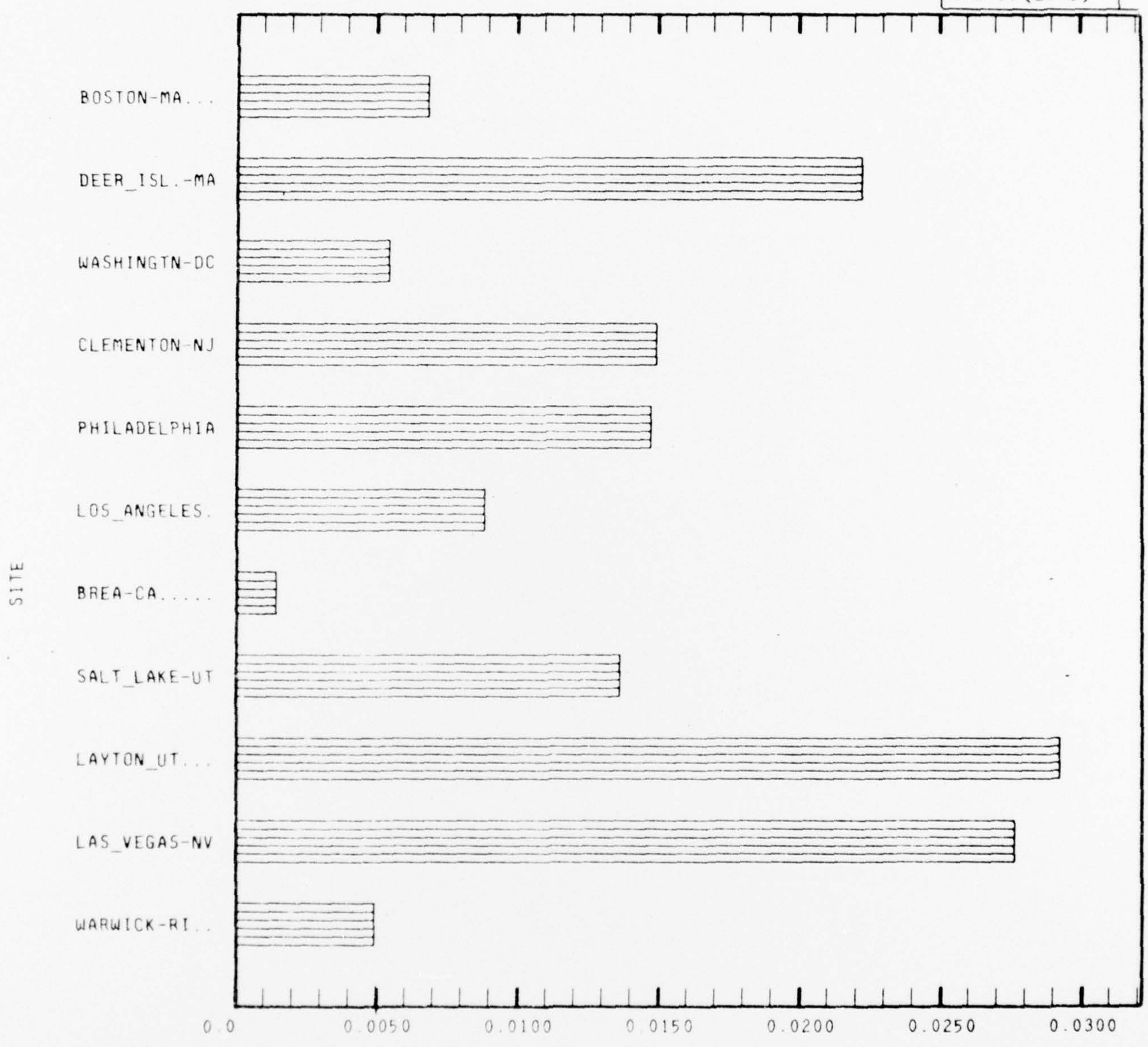


Fig. IV-9. Track number errors (2 tracks on 1 aircraft) per qualified track.

ATC-79(IV-10)

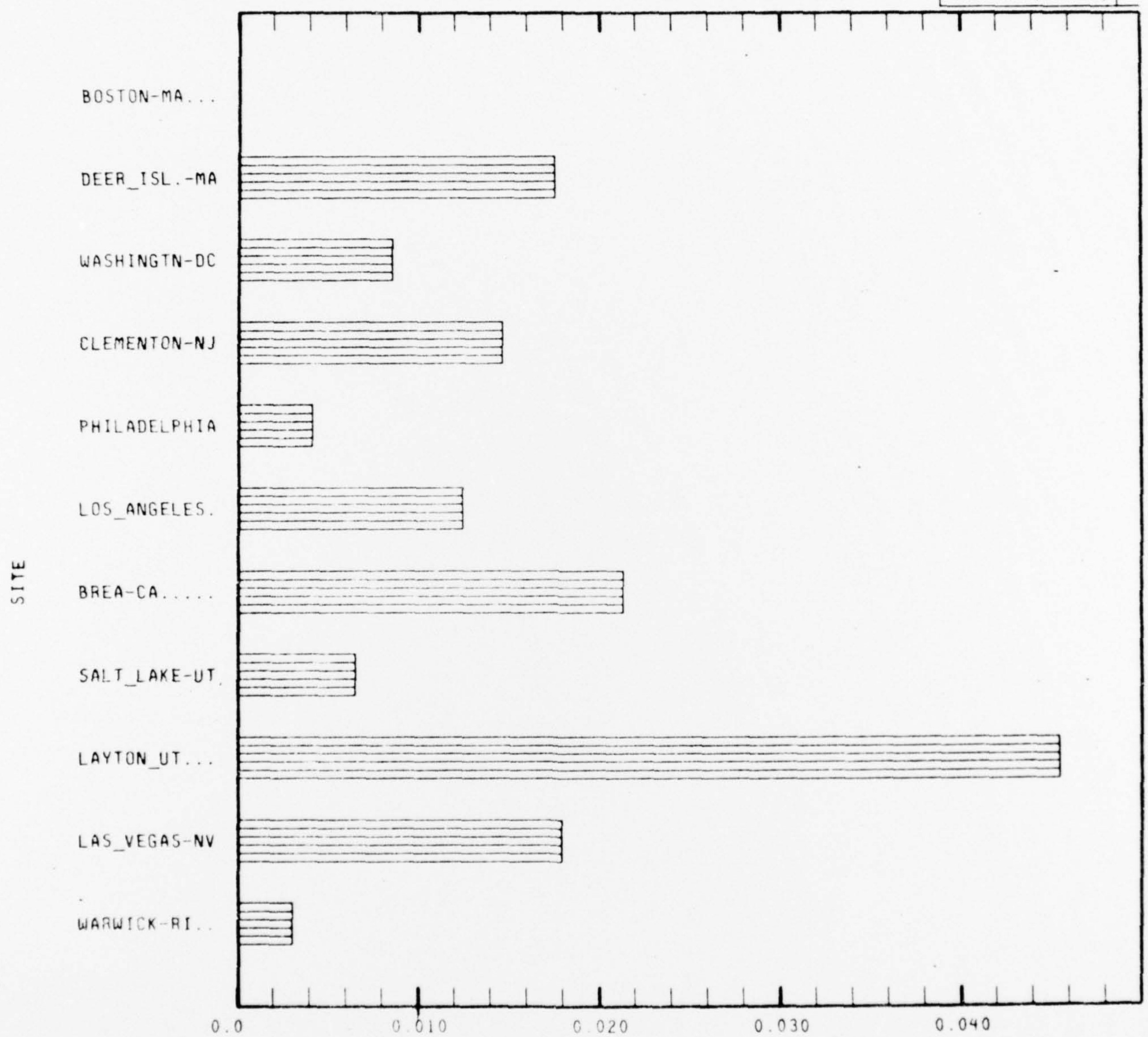


Fig. IV-10. Track number errors (2 aircraft on 1 track) per qualified track.

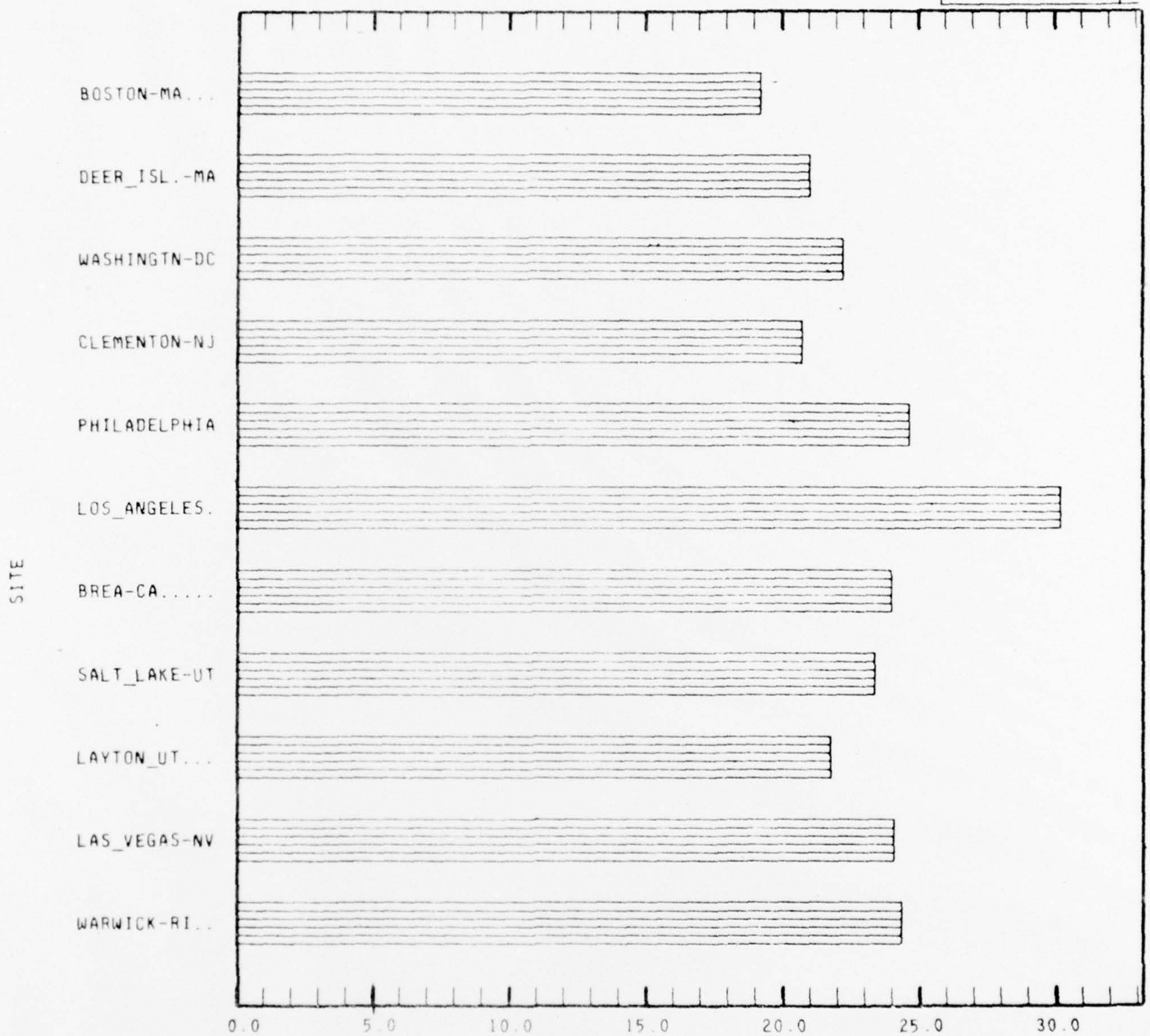


Fig. IV-11. Range error (standard deviation in feet).

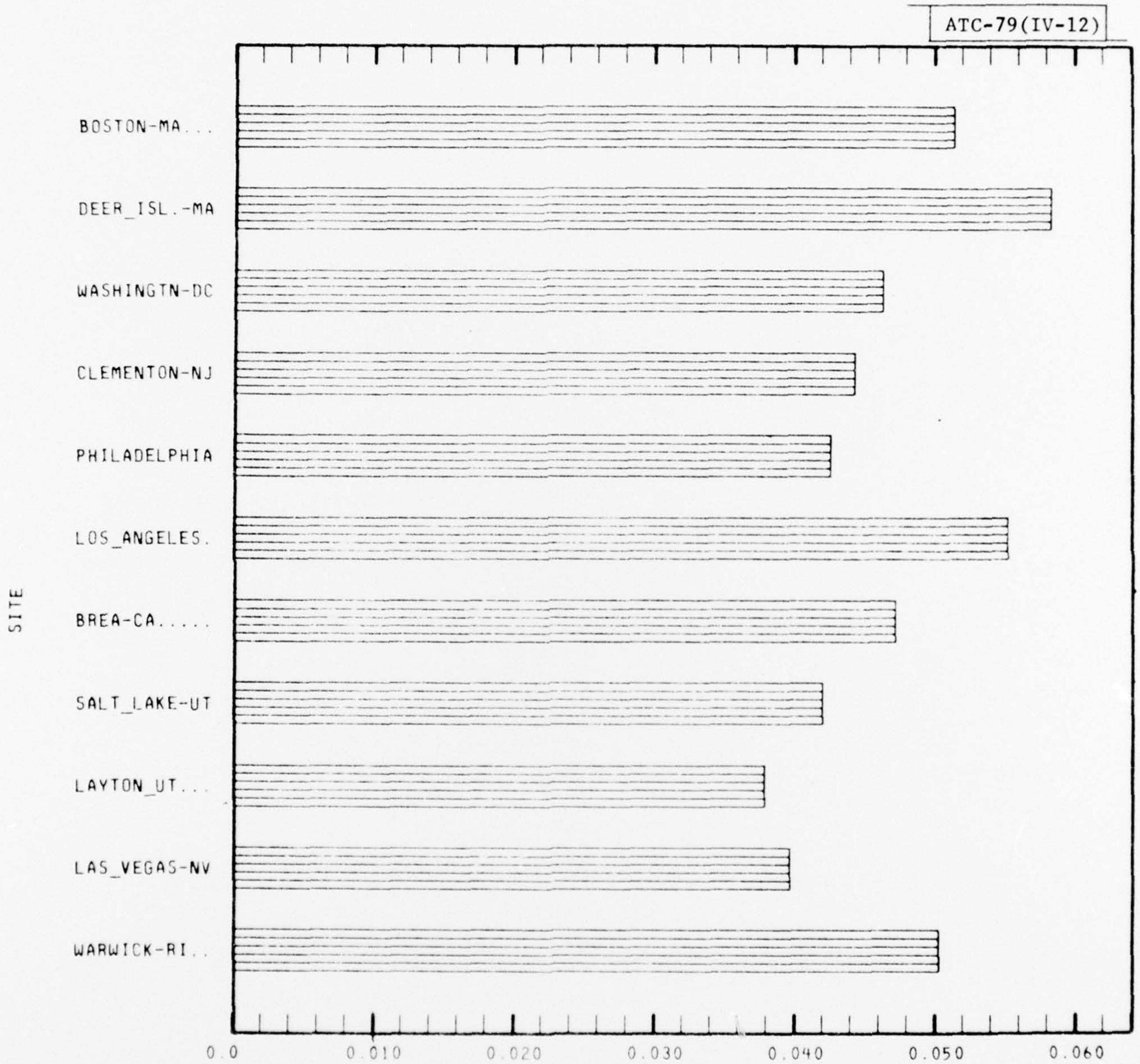


Fig. IV-12. Azimuth error (standard deviation in degrees).

pulse error will be smaller. As seen from Fig. IV-12, most sites had an error (standard deviation) between 0.04 and 0.05 degrees.

While the data presented relate to ATCRBS measurements, they are representative of the azimuth error performance for the DABS mode as well since essentially the same monopulse techniques are used in both cases.

H. Editing Out of Bad Reports

Figure IV-13 shows the percent of all reports created by the reply processor that are edited out. Recall that all sidelobe fruit and all mainbeam fruit not near another reply are dropped in the reply processor. However because the reply processor receives only about two Mode A and two Mode C replies it occasionally has replies with some bits garbled and does not have sufficient data to process them, so they are passed on to surveillance processing where data in the track file can be used to resolve the problem. Figure IV-13 indicates that from 5 to 15% of all reports are edited out in this step.

Though one cannot compute the amount of fruit from the data in Fig. IV-13, it is generally fruit that causes these ambiguous returns, so that the relative amount of fruit is crudely indicated by the bars in the figure.

Since the percentage is highest at Brea, it can be inferred that Brea had the highest fruit rates. This accounts for some of the poorer performance seen at Brea (e.g., Figs. IV-6 and IV-13), and to a certain extent at Los Angeles, where the traffic was also heavy.

I. Percent of False Reports

Figure IV-14 shows the percent of all reports that were labelled false due to known reflections. Salt Lake City, Washington, D.C., and Los Angeles

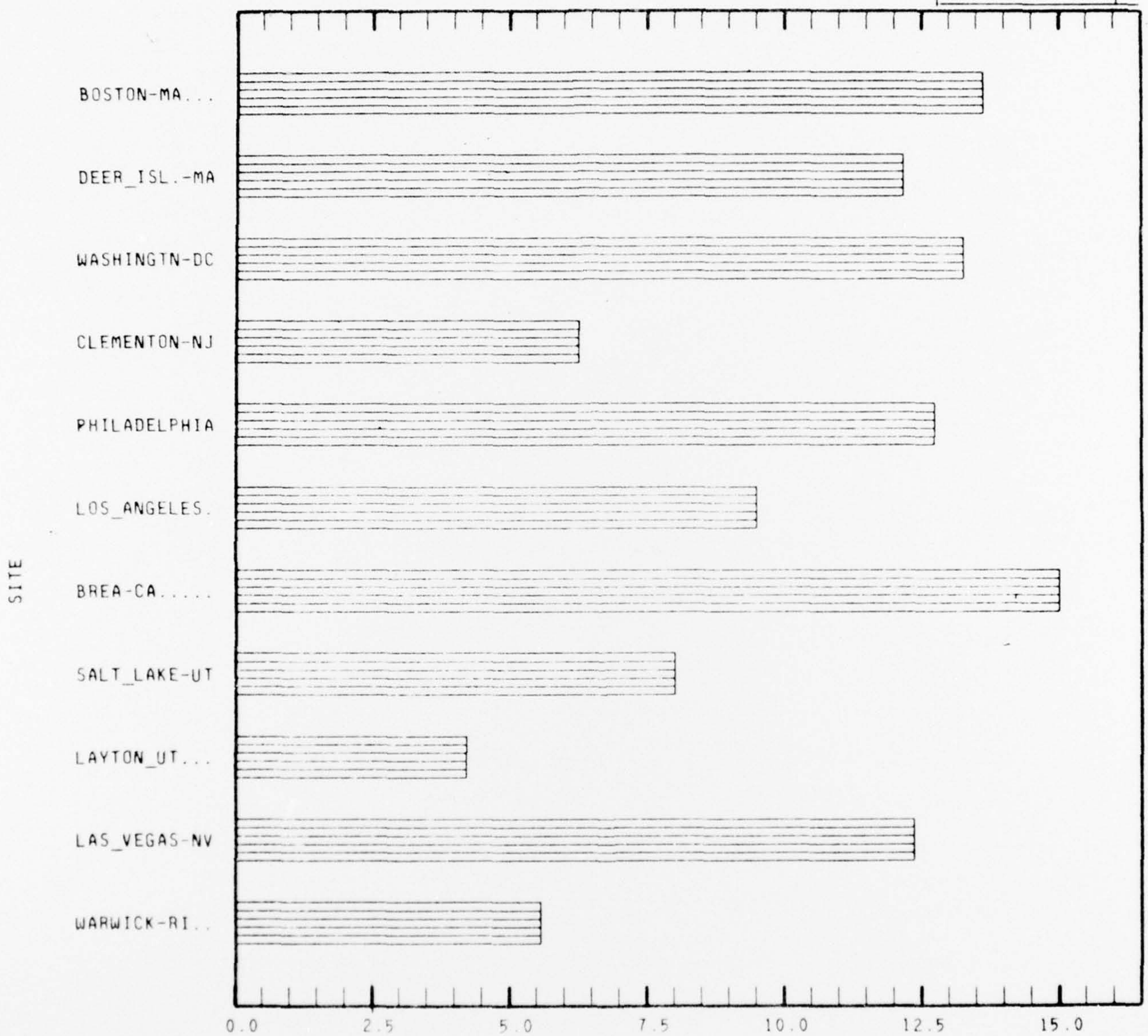


Fig. IV-13. Reports edited out (percent of all reports).

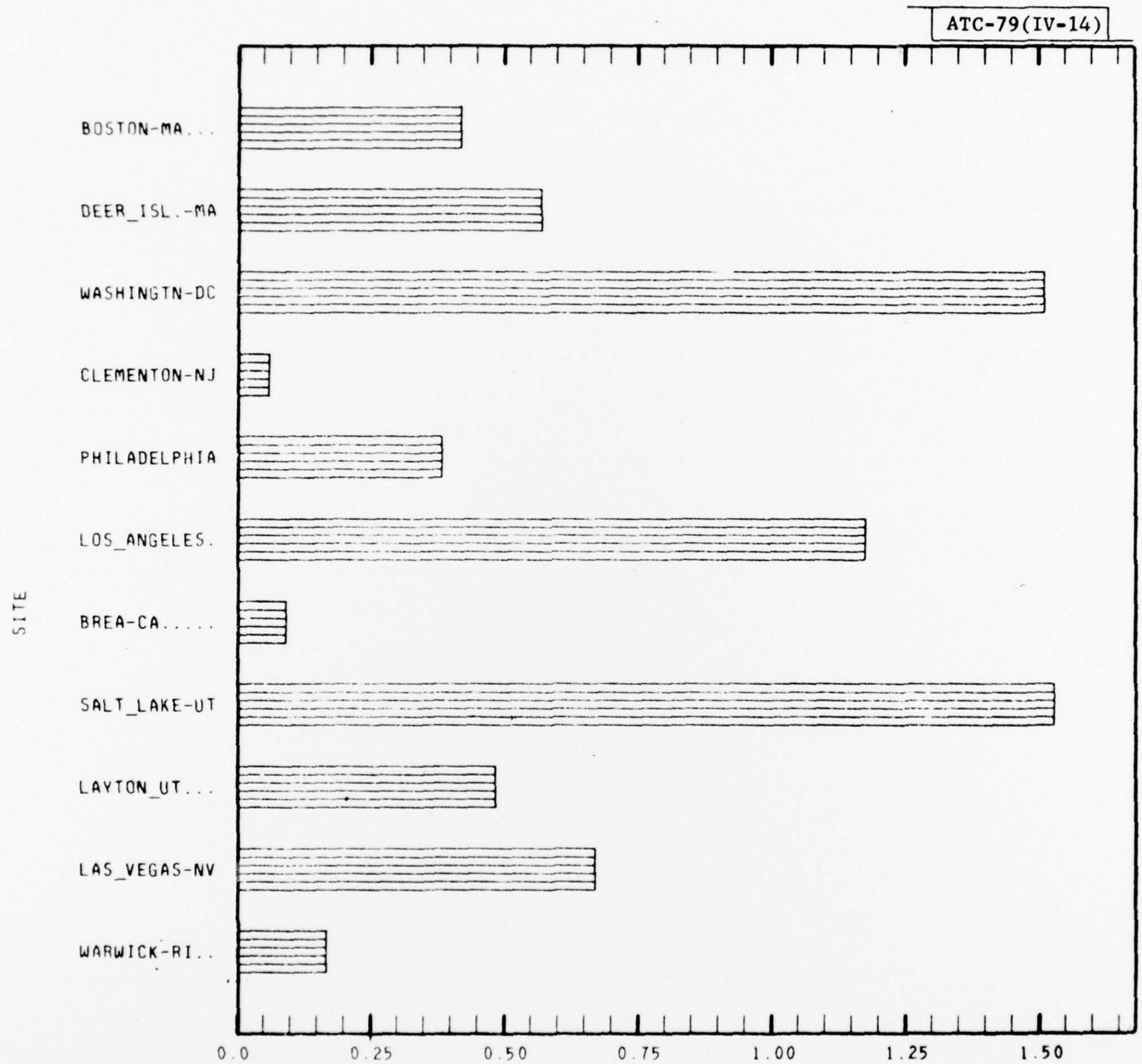


Fig. IV-14. Reports labeled as false (percent of all reports).

are the most severe. The heavier traffic at Washington and Los Angeles make their problem quite important. It should be noted that in Washington, D.C., the TMF location near the ASR-7, was actually a very poor choice because the terminal building complex caused approaching traffic on the main runway to reflect badly. Moving the TMF a short distance one way or the other would have helped considerably, and in fact the current ASR-7 location reduces the problem to about equal to that at LAX.

As seen in Fig. III-5(b), the traffic at Salt Lake City was light, but what there was of it, was largely concentrated in a NW-SE corridor. This corridor lies along a mountain ridge believed to have caused severe multipath and to have contributed to the large number of false reports.

V. SUMMARY

Based on data from tests at several different locations, this report has shown that the ATCRBS Mode of DABS performs well and that the range and monopulse performance common to DABS and ATCRBS is accurate and stable.

These data give confidence that the engineering development DABS sensors being procurred for NAFEC testing, which are functionally identical to the DABS (TMF) should achieve these performance levels:

DABS and ATCRBS Range Error (St. Dev.)	$\leq$ 25 ft.
DABS and ATCRBS Azimuth Error (St. Dev.)	$\leq .05^{\circ}$
ATCRBS Blip/Scan Ratio	$\geq$ 98%
ATCRBS Blip/Scan Ratio (Crossing Tracks)	$\geq$ 95%

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